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EDITED BY
JOHN F. DASHIELL
UNIVERSITY OF NORTH CAROLINA

An Experimental Approach to the Reading of Music

By
KENNETH L. BEAN

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AN EXPERIMENTAL APPROACH TO THE READING OF MUSIC

I. The Nature of the Problem

1. *Statement of the Problem.*—The purpose of this investigation is to determine the complexity of the musical pattern that can be perceived at one fixation of the eyes by individuals with different amounts of musical training and experience, and to study the effects of practice with a tachistoscope on the span of perception of these individuals for various kinds of musical material.

In order to make this statement clear, we must define *complexity* as used in this connection. The number of notes included in the pattern is only one of the factors to be considered. The arrangement of these notes on the staff, their relation to one another, and the way they sound when played are extremely important. Thus we may consider optical complexity and musical complexity as two more or less independent aspects of the music reading situation. A group of notes may be optically complete as a gestalt, but musically an incomplete configuration, requiring what music theorists term a resolution. The reverse is equally common. An irregularity in the optical pattern may look bad, but not sound as an irregularity at all. Since most trained musicians transfer the visual impression into the auditory field almost instantly, even before playing the notes, the effects in both sensory fields must be taken into account. How this can be done will be clear to the reader later.

The term *span of perception* seemed to the writer to be the most descriptive expression to indicate the amount of material seen distinctly at a single glance, in other words the number of notes that could be played correctly when exposed for a fifth of a second or less. This number might be constant or variable. Possibly no more than a single note could be read at a time by anyone, regardless of training. These unsettled questions pre-

sented a problem to the experimenter, which was to determine how music is read: whether by single notes or in patterns, and if by the latter method, how the notes are grouped.

2. *Need for Its Investigation.*—For years the writer has observed that many accomplished performers on musical instruments are inaccurate, slow, and stumbling readers of notes. Some of these are professionals of high standing, while others are students believed by their teachers to have exceptional talent. Nearly all of them claim to have put forth persistent effort to improve their sight-reading, with but little success, however. In striking contrast to these individuals, there are some who are not accomplished technically on their instruments, who can read at first sight the notes of anything within the limits of their ability to perform. Examples of both of the above types can often be found among pupils of the same teacher. Poor readers and good readers of all ages are to be found at every stage of development in musical training.

Violinists are, as a rule, faster readers than pianists, for the obvious reason that the former are usually following only one melodic line on one staff, while the latter must read chords on two staves and not infrequently more than one melodic line besides. Singers may be good readers or inferior ones. Many of them are not accomplished readers, even though they have only a melody to sing. Perhaps the most remarkable achievement in music reading is demonstrated by organists, many of whom can play a fairly difficult, unfamiliar composition with but few errors. In order to do this they must respond simultaneously to three continuous, independently varying successions of stimuli. The notes on the top staff must be played by the right hand. Those on the middle staff are for the left hand. The feet operate pedals for notes on the lowest staff. The three parts are often relatively independent as to time relations and direction of motion, even though they fit together according to the rules of composition and counterpoint to form one unified masterpiece. Under such conditions a well-established hierarchy of habits must carry on each mental process for a time without the focus of attention being necessary. The organist cannot be

clearly conscious of three acts at once. Exactly how he can perceive and react to so much material simultaneously is certainly not understood, but the fact remains that he does it.

The orchestra conductor has much more material on his score than he can perceive clearly if it is unfamiliar, but he needs to keep dominant in his thinking only important parts of his score, and leave the rest to his players. Even at that his task, so far as reading is concerned, is often quite difficult. How the notes tend to fall into patterns for him, if they do at all, is unknown.

All of these examples illustrate the fact that the reading of music is infinitely more complex as a mental process than the reading of ordinary printed words. In music we may find a new combination every time we turn a page—a passage that is totally unlike anything we ever played before. It is similar to a strange word that we have to look up in a dictionary. Such innovations are most frequent in contemporary music. Some players reproduce these irregular passages with remarkable accuracy, while others stumble over the most conventional themes with far too many errors, considering their experience.

Successful learning of the skill of efficient reading seems to involve a trick of which neither teacher nor pupil is conscious. Those who are lucky enough to hit upon it make amazing progress, but they seem unable to give much assistance to those less fortunate than they. The nature of the learning process here calls for investigation by psychological experimentation. Teachers are merely guessing when they invent remedies for this difficulty that are based on no good sound theory. In the reading of words the eye moves by jumps along a straight horizontal line. The most efficient type of motion and unfortunate deviations from it are well known to workers in this field. How the eyes should behave when looking at music is a more difficult and as yet unsettled question. Part of the difficulty lies in the frequent necessity of following more than one melodic line at a time, keeping the time relations of the parts as they should be, and at a steady tempo. This requirement is not found in reading words. Transfer of the seen notes to the instrument gives trouble in some cases.

Because of his own difficulty in sight-reading, the writer has interviewed a number of leading music teachers of this country on the subject. Among those who expressed their opinions to him may be mentioned Prof. Leon Sametini, head of the violin department at Chicago Musical College, Prof. Wassily Besekirsky, head of the violin department at the University of Michigan, Mme. Eugenie Wehrmann-Schaffner, nationally known concert pianist and artist teacher at Louisiana State University, and others. The three individuals named above are known to excel in reading as well as in performance. Two other university teachers among those questioned are slow, stumbling readers, but good performers. These teachers all had pupils who were handicapped in reading. They were uncertain as to the cause of their pupils' difficulty and admitted that attempts to remedy the defect had been for the most part unsuccessful. The suggestions given to the pupils differed only slightly from one teacher to another, and may be summed up in the following points:

1. The student should always look ahead of where he is playing. How far ahead he should look is determined largely by the tempo and the time values of the notes. The distance may vary from one beat to two or three measures ahead, if we give extreme cases. The value in following this suggestion lies in anticipation of the adjustment of the position of the hands in preparation to play what is coming next. One teacher has added that this interval of time between seeing the notes and playing them allows the student to digest the music mentally so that it does not take him by surprise.

2. The student should do some sight-reading every day. Any period of time in which this is not done is sure to result in loss of part or all of the improvement previously gained.

3. A large amount of relatively easy material, well within the technical ability of the performer, should be covered in practicing sight-reading. Attempting to read material that is too difficult results in stumbling and looking back to correct many errors. Thus all feeling for the time value of the notes is lost.

4. When sight-reading, one should not stop to go back and correct errors in what has just been played. This quite common practice leads to a habit of looking backward now and then instead of looking steadily forward for what is to come next, and naturally stumbling results. It is not easy for some careful performers to drive on through a piece in time when they know they are playing wrong notes occasionally, but they must force themselves to do this even though inhibitions set up because of making one error may bring about more errors. If they do not drive ahead in spite of mistakes, they will always read slowly. Of course the student must refrain from applying this principle to practice on compositions he wishes to perfect. Such disregard of errors is helpful only in increasing speed of reading.

Careful observation of the reading of skilled musicians reveals the fact that much guess-work is involved. The player sees a few cues and fills in what seems to be appropriate to complete the pattern. The effect usually sounds correct, but the notes played often fail to conform exactly to what is written. The player sees three notes in a chord that suggest to him the dominant seventh for example. Without taking time to see what the other notes of the combination are, he fills in the rest of this harmony in the position or inversion which seems to him to follow logically after what he has just played. He is likely to guess right or nearly right as to what notes belong there. Irregularities that are inconspicuous in scale or chord passages are likely to be overlooked and played as if part of a regular, conventional pattern, however.

When asked how they acquired skill in their own sight-reading, these leading teachers could think of no additional suggestions besides the above, but merely admitted that they did not know exactly how they read so fast or why some of their pupils could not do the same. The writer then suggested what was at the time his hypothesis that perhaps they saw notes in groups and not as individual notes. To this three teachers responded vaguely to the effect that sometimes they probably did see groups as wholes and not as individual notes, but that they were seldom conscious of how they did it, and had no idea of the extent of the groupings. The other teachers did not know how they read.

Teachers of public school music are now making use of what are called *flash cards* in teaching sight-singing. They hold before the class a large card with four notes or more on it, then take it away and ask the class to sing the melody. The exposure time is variable, and the technique crude, but it seems to be a step in the right direction. As no accurate measure of the results of this teaching method is now available, any detailed review of literature on sight-singing methods would have no bearing on the problem of this research, and will therefore be omitted. The fact remains that public school music teachers have no proof that the children learn to perceive as wholes the groups of notes that

are pointed out to them. An accurate measure of progress is needed, which must be the result of extensive experimentation.

3. *Its Practical Value.*—In any kind of professional work in music, whether playing or teaching, a large amount of material must be played which the performer has no time to memorize completely or even partially. Good technical background is not the only prerequisite for this sort of playing. A certain level of efficiency in reading is essential if much extra work is to be avoided. Those who play an instrument for pleasure should not be confined to what they can reproduce from memory for their enjoyment. They should be able to enjoy reading new music as they delight in a new novel. This is impossible for many, however, because their slow, stumbling reading gives rise to a feeling of fatigue and unpleasantness, and in extreme cases an emotional complex, causing complete inhibition at the sight of printed music. Often a slight deficiency is made much worse by an over-severe teacher who "explodes" at every wrong note the pupil plays. The resulting mental attitude takes all the pleasure away from reading the printed page, and causes a careful note-by-note analysis of all new music, which is necessarily slow. Frequent backward looking to see if all is going well results from a fear of making mistakes and provoking the teacher's disapproval.

The practical aim, then, of this investigation is to help the teacher to find the individual difficulty of each pupil in music reading, and to correct the defect. This problem is essentially one in applied psychology, though its theoretical aspects are to be brought out also. We do not claim that the secret of efficiency in the skill under consideration lies entirely in the application of any one principle of psychology. Complex skills must go through many stages before perfection is finally attained. The child must learn what to do in response to every note on the staff when he is a beginner. He must automatize this response so that he does not have to think about it. He must attain some speed in manipulating his instrument. Then comes a final stage in the learning process having something to do with rapid perception

of notes and quick, well coördinated response to them. This step is the one least understood, and the one in which the writer thought the gestalt principle might play an important part. Out of such an idea the writer got the basis for his experiments to find out what we do with music when we read it.

II. Discussion of Literature Related to This Study

1. *Studies of Music Reading.*—For nearly twenty years music teachers have pointed out certain note groups to their pupils. They have asked the pupils to learn how these groups look, but they had no measure of the pupil's ability to respond to these groups as wholes. In fact they had no notion as to what patterns of notes they themselves read ordinarily. Various methods of teaching music reading by sight singing have been attempted. The use of the conventional fixed *do* system was followed by the American movable *do* with syllables for chromatic tones as well as those of the diatonic scale. This was complicated, and whether it was any better than the older system may be questioned. Numbers have been substituted for syllables in some schools. These systems have brought results, but work with them has been based upon opinion and not upon scientific experiments. Therefore detailed consideration of them will be omitted here. The study of harmony and counterpoint acquaints the student with patterns in music in greater detail than merely playing an instrument. The specific effect of such study upon reading is not understood, and has never been measured. The crude methods of note group reading on flash cards, recently used by some teachers, measure nothing with any accuracy as to progress, and the selection of material for this purpose at present is not based on experimental study. However, a more careful use of flash cards may prove to be a step in the right direction.

Possibly the clearest advice given by any musician on reading is to be found in the following quotation from Joseph Hofman (6): "For improving the facility in sight-reading, you must do much reading or playing at sight as fast as possible even though at first some slight inaccuracies may creep in. By quick readings you develop that faculty of the eye which is meant by 'grasp,' and this in time facilitates your reading of details. . . . A large part of sight-reading consists of surmising, as you will find upon analyzing your book reading."

This statement suggests pattern reading vaguely, but gives no clear explanation of exactly how it is done.

Scientific research on music readng has been done by Jacobsen (7) and later by Ortmann (9). Jacobsen photographed eye movements with a horizontally moving film for one eye and a vertically moving film for the other, in order to be able to pick up motion of the eyes in any possible direction. He used ten adult subjects. The music was played on a small reed organ. Only one of his subjects had ever played organ before. Errors were recorded. If a whole chord was played wrong, this was counted as only one error. Fixations were found to be short in good readers, and few regressions occurred. If the reading speed exceeded the playing speed, some mistakes resulted. Errors crept in also when too large a pattern was attempted, because the group was not grasped well.

If the tempo of the music was slow, one fixation occurred for every one or two notes, as often one as two for good readers, for one-part material. If the

melody was faster, three notes on an average were taken in with one fixation by good readers. Poor readers made one fixation per note, or even two on long notes, with some regressions to make sure of the key signature. Often a fixation was not right on a note, but near it. Fixations for all subjects were more numerous at a normal rate than when speeded up by a metronome. The number of fixations for a simple melody ranged from 30 to 62 in the group. There was one fast reader who made up for his excessive number of fixations by making them very short. Average length of a fixation varied individually from .32 second to .76 second. One subject had extremely long fixations, but few of them. He was a slow reader, however.

Two-part material worked out in a similar fashion, but the errors were all in the lower part, which, naturally, was taken to be of secondary importance compared with the top melody. At least the subjects seemed to give more careful attention to the upper part. An average of one fixation for each pair of tones was made, and 30 to 48 pauses were necessary to read a two-part selection.

Reading of three-part material required many movements horizontally, vertically, and diagonally from the one staff to the other. The reader is referred to Jacobsen's interesting diagrams to see exactly how this took place. It was evident that the performer had to remember one part while playing the other, and look ahead to anticipate what was to come next. Jacobsen found that little guessing was done. Everything was perceived. Any irregularity in a pattern, such as varied rhythms, accidentals, etc., caused an increase in the number of pauses. If errors were made, the same effect was observed on the film. At a normal tempo, the players averaged 67 pauses for a three-part selection. The same at a faster tempo gave an average of 47 fixations. The good reader, according to Jacobsen, looks considerably ahead of his playing, but the poor reader is not much ahead. The experimenter did not give exact data on how far ahead each looked, but such facts might be interesting.

Jacobsen found that the less experienced readers must take more time to get both hands successfully than to grasp notes for only one hand on one staff, but the mature reader can maintain the same speed for reading on two staves. The number of regressive movements back to groups that were probably forgotten increased with the three-part material.

Four-part music illustrated the same principles, except that more notes had to be grasped per fixation in order to play it up to time. Good readers grasped as many as six notes at one pause, according to Jacobsen. The average span of the subjects was much less than these exceptional instances, however, varying individually from 1.95 to 2.97 notes per fixation. Errors did not increase in proportion to the number of parts added, but most of them did occur in the bass for the four-part material as before. In this case the fixations on the two staves were about equal in length and number. Movements were in all directions as before.

Good readers were found to read chords from the top down, not from the bottom up, as a rule. Few exceptions to this were found. Poor readers look at one note at a time until they have built up the entire chord. They are likely to begin at the bottom as often as at the top.

Jacobsen found that his subjects who had relatively little training did not make many more fixations than the highly trained performers. Some of the former made fewer pauses than the latter. All of his subjects made errors on this simple material. The fastest readers were the most accurate, however,

and they differed only in the fact that some of them made many short fixations, and others made fewer, longer ones. In every good reader, retention proved to be a large factor.

Ortmann (9) made a study of the reading of 45 chords. He exposed each $\frac{1}{25}$ second to each of his subjects, who responded by writing the notes. Two to six notes were included in each chord, which was not necessarily in harmony, but might be any consonant or dissonant combination. The observer seldom failed to get the correct number of notes, but he was often uncertain as to their location. More errors were made if the group of notes was spread over an octave or wider than if it covered a fifth or less, regardless of the number of notes. There was a tendency to underestimate the vertical distance between the notes. Horizontal dimensions were sometimes involved when two notes were on adjacent scale steps so that they could not be written under each other. Interpretations of the results stressed the importance of the visual pattern. Subjects did not think of the tones or the names of the notes. Some looked for octaves and fifths, around which the other notes grouped themselves. Several possible correct ways of writing the same chord occurred, but ordinarily the subject reproduced the design as he saw it. Some saw most clearly the middle part of most chords, or the part where notes were closely grouped. Introspections revealed that 96 per cent of the subjects read from the bottom up except for close groupings, in which direction was unnoticed.

Ortmann (9) suggested that chord unit reading is analogous to word reading as against mere letter reading. If a "good chord" was shown, the results were better than for an unfamiliar grouping. Notes were more frequently misread by one step than by two or more. Mental set had an effect. An unexpected chord was missed usually, while if a familiar one came along, it was read easily. About 15 per cent of the observers did not think of the clef used, the names of the notes, or the chord, but only the visual pattern. Ortmann says, however, that more was involved than mere visual grasp. He admits that he covered only a part of the process in his study. Interesting individual differences appeared in the results. Some good readers and some poor readers served as subjects. The amount of training varied considerably also.

2. *Criticism of These Studies.*—In the opinion of the writer Jacobsen and Ortmann have both given some valuable evidence in favor of the view that good readers of music read patterns of notes, while inefficient ones read individual notes. They have not gone far enough, however, to show how various kinds of music may be grouped by different readers. Their material was limited. The individual differences among music readers at all stages of advancement is an extensive field for study by no means covered by these two investigators, who used a limited number of subjects.

After examining the record of the errors made by Jacobsen's subjects on his relatively simple selections, the writer has concluded that Jacobsen did not have any excellent readers in his group. There are numerous musicians everywhere who could have exhibited better performance, and some record of how they achieve it would be interesting. A greater number of subjects should participate in such an experiment in order to be safe in generalizing about good readers or poor ones.

Jacobsen's selections demonstrated effectively what is done in following one, two, three, and four simple parts, but few rhythmic variations entered in. The material was not extensive, nor was it varied in nature. The questions of how complex rhythmic relationships between the parts may be perceived or what

the reader does with a seven or eight-note chord are not yet touched upon. The study of the effect of practice in reading conventional and ultra modern types of music upon the eye movements made with these kinds of material would throw some light upon the part played by past experience. These possibilities have been pointed out in order to show that Jacobsen has described only a small part of the behavior of a few music readers, and that his conclusions may be valid only with the kind of music that he used.

The writer objects to Jacobsen's use of a small reed organ on which his subjects played the selections, because all but one subject were unfamiliar with the organ, and could have done better on the piano, which they had played before and to which they were accustomed. How much the unfamiliar instrument distracted their attention from the reading would be difficult to determine, but it might easily have interfered with good results.

Another criticism that might be made is that the type of camera Jacobsen used, with a vertically moving film for one eye and a horizontally moving one for the other, is subject to certain inaccuracies. Without doubt it is complicated, and some claim that such a camera is unsatisfactory. If the eyes of the subject always moved together and fixated the same point, possibly other sources of error would be too small to affect the general result, but the writer questions whether Jacobsen was safe in assuming that he had located the fixations correctly in spite of the defective coördination so frequently found in the two eyes of many individuals.

A consideration of Ortmann's work shows that his material was limited in scope. His patterns were in many cases mere chance combinations, unlikely in music. He did not have his subjects play the patterns on an instrument, which is the usual response in reading music, but he had them write the notes. This required more time and effort, and was not the same mental process as the typical reading and playing situation calls for. In order to write a chord, a vivid memory of it must somehow be retained for a much longer time than would be required to play it. Also one may observe from the results that many subjects did not think of tones, letter-names, or clef signs, but only of visual patterns. In such a case were these patterns music or were they mere visual forms? One can answer this question by stating that unless the visual forms meant tones to be heard or played by the subject, the response was not that of reading music as we usually think of it. Possibly this difference in the response accounts for the disagreement of the two investigators as to whether chords are usually read up or down. Chords should be thought of in terms of the clef sign used, the key signature, and the use of the two hands (or one in some cases) to play them, etc. The visual pattern is important, but it is not the whole process.

A question might arise as to why Ortmann exposed his chords $\frac{2}{5}$ of a second. This is twice as long as one fixation of the eyes. One could not discover whether the subject took in the form instantly as a whole or read it by parts, since either method was possible with this long exposure. A shorter time for seeing the form would have given a more accurate measure of the span of perception.

In spite of the disadvantages of Ortmann's method, however, his observations concerning the nature of the errors are interesting and valuable. He suggested the idea that chord reading is analogous to word reading, and presented some evidence to indicate that this is true, but he gave little in the way of an explanation of how we learn to group notes into certain patterns. His material was not extensive enough to furnish adequate description of the chord reading process, which needs further study in a more typical situation.

III. Apparatus, Materials, and Procedure

1. *The Twin Tachistoscope.*—Since the subjects in this experiment were expected to respond to musical patterns by playing them in most instances, a tachistoscope that could be mounted on a piano was necessary. The use of a tachistoscope of the usual sort placed beside the piano would require the subject to turn his head far out of the natural position for reading music at the keyboard, therefore any such plan was abandoned. The experimenter felt that the conditions for the work should resemble the ordinary music-reading situation as closely as possible. Therefore he designed apparatus that would make these conditions conveniently possible.

Also the experimenter saw the value of testing more than one method of responding to these musical stimuli, because the subject might in some cases experience difficulty and confusion in attempting to transfer what he saw to the keyboard, even though he perceived accurately what was there. How much of the subject's difficulty was in reading and how much of it was in the mere mechanics of playing would not be easy to establish without some kind of a check on this point. The experimenter believed that a comparison technique would be useful for this purpose. Two stimulus cards might be presented in succession, with equal times of exposure and a constant interval between. The task would be to tell whether the two patterns were alike or different, and, if possible, what the difference was, if they were unlike. If the subject could notice a small difference every time one occurred, he was seeing the whole (the configuration), and if he could locate the difference exactly, he was getting the details of the pattern as well as its general form.

This type of comparison experiment could be done with rather elaborate apparatus of a sort now in use in some laboratories, except for the difficulty of mounting such a bulky instrument upon the piano for the other method of response. Conditions should be as much alike as possible in the two kinds of experiments, therefore the same machine ought to be used throughout. The Twin Tachistoscope has the advantage of being mountable on any piano, simple to construct, easy to operate rapidly, seldom in need of repair, and accurate enough to give reliable scientific data.

The instrument, which is illustrated in Fig. 1, is entirely of wood except for the wheels, braces, and smaller parts. The screen is made of 3/8-inch five-ply wood, for durability with a minimum of weight. The blocks, which rest at the ends of the keyboard, are adjustable by sliding them along the board fastened to the lower edge of the screen. The metal braces, padded at the ends that clamp to the piano, are adjustable to pianos of different height. These give additional support to the instrument so that it will not fall forward upon the subject. The two windows in the screen, through which the stimuli are seen, are 2½ inches square. The screen is 8 inches above the keyboard to allow the hands ample freedom for playing. The discs are 20 inches in diameter, and are constructed of heavy galvanized iron painted black on the back side to reduce glare. On the front side, toward the subject, the discs are painted gray to reduce the amount of change in intensity of the light when the card is exposed. If the discs were black on this side, the contrast involved in each flash would be greater, a phenomenon which tires the eyes of some individuals. Bicycle hubs reduce friction to a minimum, and yet hold the discs rigidly in position so that they do not sway when in motion. Mounted on each disc is a fixed weight of lead in a galvanized iron pocket and a movable counterpoise weight that can be tightly fastened by a screw at any desired point along a bar on the radius of the disc. This weight, which is of the same material as the

Front View of Twin Tachistoscope mounted on a piano.

Subject reads card flashed in left window, then plays the notes.

Experimenter at left has just pulled the trigger.

FIG. 1

Back view of Twin Tachistoscope. First disc has completed its swing, and the second is in motion.

other, but slightly lighter, regulates the speed of rotation. The gap in each disc is so cut as to expose the card during the fastest motion of the wheel as it swings. This means that a diameter drawn perpendicular to the one on which the two weights are located passes through the exact middle of the gap. Since the wheel works on the principle of the counterpoise pendulum, the fastest motion occurs at about the time the gap passes the window, making the opening and closing of the exposure as quick and inconspicuous as possible. Any differences in weight or form of parts of the two discs that may have escaped notice in spite of great care in construction were too slight to cause any inaccuracy large enough to be observed.

At the extreme right of the back view of the apparatus may be seen the trigger which releases the fixed weight of the first disc, allowing the weight to fall without a push from any part of the trigger. After it has swung to the other side, the weight is caught by the latch on top of the small triangular board between the discs. No backward swing is possible until the experimenter pulls the latch into its original position. If the second disc is to be used, it is set before the first one is released, in such a position as to fit the left prong of the latch into a notch in the disc. Thus set, the weights are in position for a swing opposite in direction, but exactly equal in extent to that of the first disc. When the fixed weight of the first disc strikes the latch, its left prong is jerked out of the notch in the second disc, the fixed weight of which falls and is caught near the end of its swing by two springs fastened to the latch board. This disc remains there until set for another swing. All parts operate silently, since rubber padding was used at all points of contact of the latch, springs, or trigger with any parts of the discs.

The regulation of exposure time was accomplished by marking points along the bar at which the sliding weight could be set for certain desired speeds. The determination of these points was made with a Hipp Chronoscope, for which electrical contact was made and broken by a device constructed for the purpose. The contact system consisted of a metal bar fixed to the edge of a window in the screen and a flexible spring that would touch it unless kept a very short distance from it by pressure against the disc. When the disc was in motion, the spring, which was small, made a negligible amount of friction against it, but enough to keep it 1/16 inch from the bar, approximately. When the gap reached the window, the spring was instantly released against the bar, making contact, which was later broken by pressure of the other edge of the gap against the spring, quickly pushing it off of the bar. For the purpose of this experiment, an exposure of slightly less than a fifth of a second was desired, since this has been considered the best time for tachistoscope work. During such a brief exposure, the eyes cannot shift from one part of the stimulus card to another, but must take in everything at one fixation. Thus a measurable unit of perception can be obtained. The range of times possible with the Twin Tachistoscope was found to be from about 2/3 second to 1/20 of a second, but the most desirable exposure turned out to be .187 second as an average of 20 trials. The total range of variation of this time did not exceed .005 second for these 20 measurements. Much work was required in reducing friction and adjusting nuts on the hubs before this degree of reliability was finally reached. More tinkering was necessary before the second disc was at last synchronized with the first so that its exposures averaged .185 second in 20 trials with equally small range of variation. Of course crude synchronization was achieved first by allowing both discs to swing freely many times, adjusting the sliding weight of the second until it went with the first for several swings without perceptible deviation. As soon as the speeds seemed the

same for some time, the contact device was shifted to the other window for a test, with the result that, after further small adjustment, reasonable accuracy and dependability were attained.

The card support is of galvanized iron, and can be swung out slightly to facilitate card mounting. Considerable care must be taken to avoid setting up a vibration of the support when releasing it with the hand, but with practice this can be done easily. The support is long enough to hold a card with two stimuli, one before each window, but it may be used for a single stimulus card to appear in one window only. The card is held at a slant that is about parallel to a sheet of music at the rack of the piano, and is about a half inch behind the window at the bottom.

Illumination is furnished by two 60-watt bulbs in a double socket, projecting from the screen at an angle such that there is no glare on the stimulus card at any point. The lights are not visible to the subject when the exposure is being made or at any other time. Care is exercised to have the room dimly lighted with no glare anywhere that will shine in the subject's eyes. Intense light on the front of the screen is avoided, since under such a condition the subject's eyes would tend to follow the small irregularities in the surface of the discs as they turn. Such irregularities are inconspicuous in dim light, and steady fixation is undisturbed. Many lighting schemes were tried before a successful one was found. The importance of eliminating all distracting stimuli and glares, even though slight in intensity, was revealed in preliminary experimentation with the Twin Tachistoscope before any results for actual use were obtained. No set of conditions will please everybody. The 60-watt bulbs gave too much illumination for some individuals, but reduction of the intensity caused others to complain that the cards were not sufficiently lighted. In general subjects quickly became adapted to any feature of the apparatus that bothered them during the first few trials.

A problem arose, in connection with the use of the machine, as to how a satisfactory fixation point for the eyes might be located. Workers with the tachistoscope who are careful about this matter have the subject fixate a point in the middle of the area to be covered by the material to be seen. This seems to be a logical procedure, and works out experimentally for the best if the material consists of a word or a row of dots. Unfortunately, however, the musical patterns for this research were irregular in form in many cases, and almost never on a straight horizontal line like a word. Therefore the arrangement of a group of notes on a card in such a way that a fixed point of gaze would always fall in the middle of the group was next to impossible. Where the middle would be was in some cases debatable. Yet the experimenter knew that wrong fixations would cause a part of the pattern to lie outside of the area of clearest vision, and thus lead to errors. Therefore he placed a square of smooth, clear celophane over one window, with a black ink dot in the middle of the square. The dot was very small, but clearly visible before exposure was made. Applying a wet, sticky mixture to the edges, the experimenter was able to shift the celophane easily and have it stay where he put it. As a part of the preliminary experimentation, he then tried to find the best fixation point for himself and later for two other individuals on several musical patterns. The results were so confusing and conflicting that the establishment of a best point of fixation for each pattern seemed to difficult to be worth the time and trouble necessary to do it. Therefore this phase of the problem was set aside in order to find out more important things about music reading first. Some means of control of fixation that will be adequate for reading music on cards will have to be worked out as a separate experiment in the future.

In reading notes from the page, the performer sees in the periphery of his field of vision whether what is to come next goes up or down. Probably he uses this vague cue to anticipate what he is to do next, at least to the extent of knowing where he must look for the next group of notes. He is playing some notes below the staff, for example, which at the time fall on the fovea, and are seen clearly. While doing this, however, he perceives vaguely, out in the periphery of the field, that the next measure jumps to the top of the staff and runs up above it. He anticipates this change, and shifts his eyes to the right point to bring out this next group clearly.

Reading in the Twin Tachistoscope, the performer has no opportunity to anticipate the direction of motion of the music before he actually fixates it. This leads to many wrong fixations, and reports such as, "I didn't see that at all," unless verbal directions are given as to about where to look. Therefore if the music about to be shown changed from below the staff on the preceding card to above the staff on the one to be seen next, the subject had to be told to expect notes above the staff. Even with the greatest of care in cutting and pasting music on the cards so that the staff would fall in the same location in the window, and with directions where to look when this seemed necessary, some errors were undoubtedly caused by wrong fixations, and not by inability to perceive as a meaningful pattern what was presented. These cases constituted a minority of the errors, however, and were identified introspectively as wrong fixations by the subject as far as it was possible for him to do so. In some instances the subject was sure that he had looked too high or too low, and another trial on the card was given him. If he was not sure this caused him to fail, no second chance was allowed. Unfortunately this uncontrolled factor in the use of the apparatus could not be avoided, but the writer believes that it affected the results very little. The Twin Tachistoscope has proved itself of value, in spite of a few imperfections, for accurate measurement of music-reading efficiency and progress in both speed and accuracy. It has made clear many individual difficulties not understood by music teachers, and has helped to correct most of these faults.

2. *Selection of Material.*—The music to be read was mounted on cards 3 inches long and 2 inches wide, care being taken to have the staff, or two staves in some cases, in identical position on every card. Printed music was cut up into fragments, which were put on the cards smoothly with Duco Household Cement. In a few instances, printed music could not be found which would illustrate a desired type of pattern well. Therefore manuscript patterns were made with a pen as nearly like printed music in form, size, and every other respect as possible. The notes were of the average size found in most printed sheet music. Variations in the size of the staff were too small to make any difference.

The material was divided into three types of music: (1) melodic, (2) polyphonic, and (3) harmonic. Under each heading came groups of cards of increasing difficulty from the simplest possible to the most complex. Sixteen series of cards

were prepared for practice, and an extra series, half of which was testing and half for trial previous to practice. The total was 680 cards. Each series contained 40, with the exception of C and D, which had 50 in each. Series A, B, C, D, and E were made up of melodic passages only, increasing in difficulty from one series to the next. Polyphonic music (having two or three relatively independent melodic lines) furnished the material for series F, G, and H. Part of this music was on one staff for one hand and the rest of it was on two staves for both hands. The latter was far more difficult to read in a short time. Here again the complexity increased as in the melodic type. Chords of two, three, four, five, and six notes (or even more in a few cases) were selected for series I, J, K, and L. Some of these were for one hand, and some for both. They included triads in their various inversions, seventh and ninth chords, and altered chords, etc. Unclassified material of unusual sorts, rhythms, arpeggios, and queer modern melodies fell in series M, while N, O, and P were double exposures for comparison as explained before. These last three covered the three types of musical patterns of the previous series, with fewer examples of each, however.

Some of the melodic patterns were composed by the writer to illustrate the relative difficulty of perceiving certain intervals between notes, and to show the effect of distribution of the notes on the staff upon the ease with which they may be perceived. Other brief portions of melodies were selected from the Bach Sonatas for violin unaccompanied. These passages were chosen because of their good melodic character and their freedom from accompanying harmony. Melodies of a more modern style were selected from the works of John Alden Carpenter and Samuel Gardner, both contemporary American composers. Bach again came into our polyphonic series, naturally. Chords were selected wherever they could be found arranged as desired.

The comparison stimuli duplicated in type, but not in exact notes, each kind of pattern used on the single cards. The checking of one technique against the other which this made possible proved to be of great advantage in understanding the results. The selection of stimuli was not a mere random choice. Each

pattern of notes used illustrated a point in regard to the difficulty of integrating a certain type of configuration. Professor Max Wertheimer, who is accomplished in music as well as in his own field, psychology, gave the writer a number of suggestions as to what constitutes complexity in a group of notes. He pointed out that one must distinguish between optical completeness and musical completeness of a pattern. A configuration of notes may look complete and sound as if something is missing that should bring it to a satisfactory conclusion. Likewise a pattern may be all there as far as our auditory impression is concerned, but appear visually incomplete. Optical irregularities in an otherwise symmetrical ascending and descending passage may have a profound effect upon its perception as a whole, according to Wertheimer. Numerous illustrations of the phenomena described above were discovered and added to the material.

Dr. Martha G. Colby, also accomplished in music as well as psychology, suggested the use of patterns from contemporary music that would not be conventional in form so that the part played by past experience would be equal for all subjects, since the patterns would be new to them. Some such material was included in series L and M. She also pointed out the importance of control of the tempo at which the music was played. In preliminary experimentation, the writer found rigid control of the tempo by means of a metronome undesirable for the kind of practice to be done. Attention to a metronome or to keeping a given tempo too exactly distracted the subjects, seriously hampering them in their attempts to get as large a group of notes as possible at a glance. Therefore control of tempo was confined to the simple instruction: "Play it at a convenient, moderate tempo." This direction was carried out with fair success.

Preliminary trials also revealed that the cards were read as isolated units, and not as parts of a logically continuous composition. Reversal or rearrangement of the order of a logical passage read by single cards did not confuse the subjects or materially reduce their efficiency in reading, strange as this may seem. That fact was favorable for the procedure used, since on the difficult cards the subjects made errors mostly at the end,

making the material sound illogical to them anyhow. Therefore succession did not operate as it does in continuous reading, as an aid in the anticipation of what is to come next. Hence logical order was not followed strictly in all series, though in some the material was in succession as in the composition chosen.

The piano technique required to play the material selected was limited, so that all subjects who play with a fair degree of efficiency should find the response to these stimuli no more difficult than pronouncing a familiar word correctly. The motor response was further facilitated in that the subject was allowed to play the card again if his finger struck a key not intended. This seemed only fair, since the best performers make such errors occasionally, and correct reading rather than playing was to be considered.

Fig. 2 shows examples of the music which the subjects read. The material as shown here is crowded together to save space, and is not distributed as it is on the cards. The illustrations are in smaller notes than the average sized printed ones on the cards. These examples will be referred to again in discussion of the results.

Difficulty was encountered in preparing material because of the presence of distracting stimuli such as fingerings, signatures, accent marks, etc., on nearly all music. Better results might be obtained with no markings, just notes and staff, on the cards. On the other hand, these markings are a part of the pattern in ordinary music reading just as punctuation belongs on a page of printed prose or poetry. Leaving them out would make the situation unnatural. Many markings of expression and fingerings must be disregarded in a first reading of a composition, because attention is on the notes and their time values if the music is at all difficult. Therefore some markings were allowed in the material, but the subjects were not required to observe them. Since holding a signature in mind is essential to good reading, signatures of several sharps and flats were included. The experimenter gave these to the subject verbally before presenting the first card to him, and made note of any failure to observe the signatures throughout.

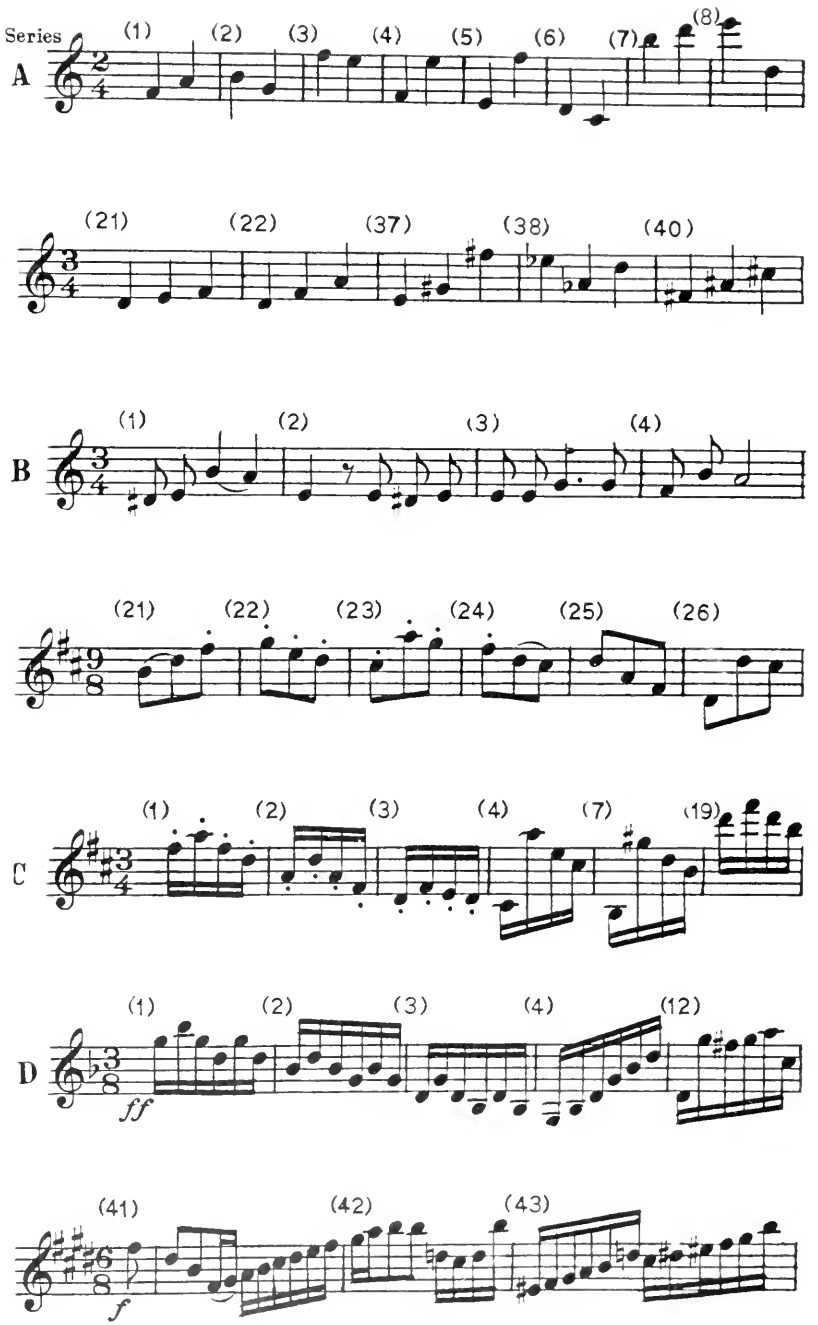


FIG. 2
Samples of music selected for the cards.

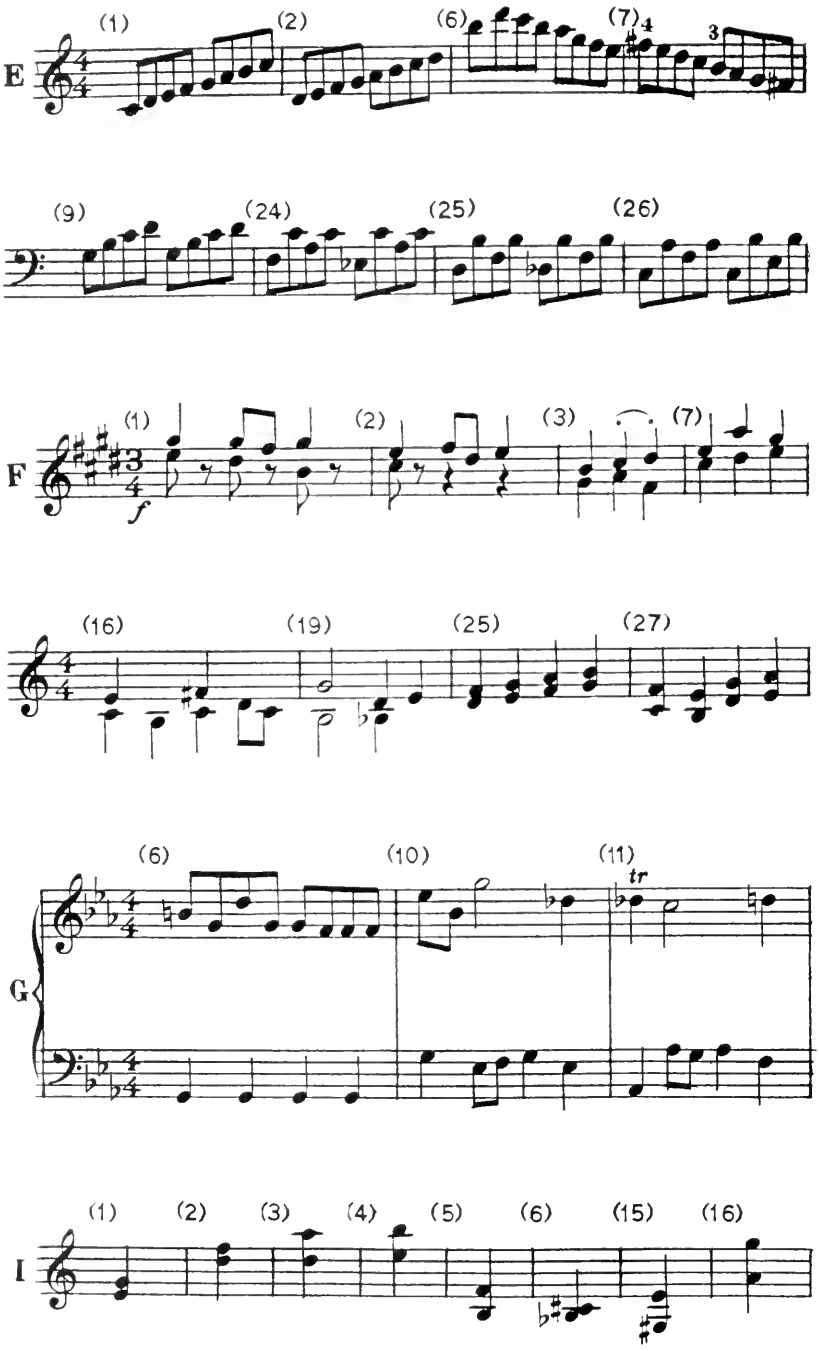


FIG. 2—CONTINUED

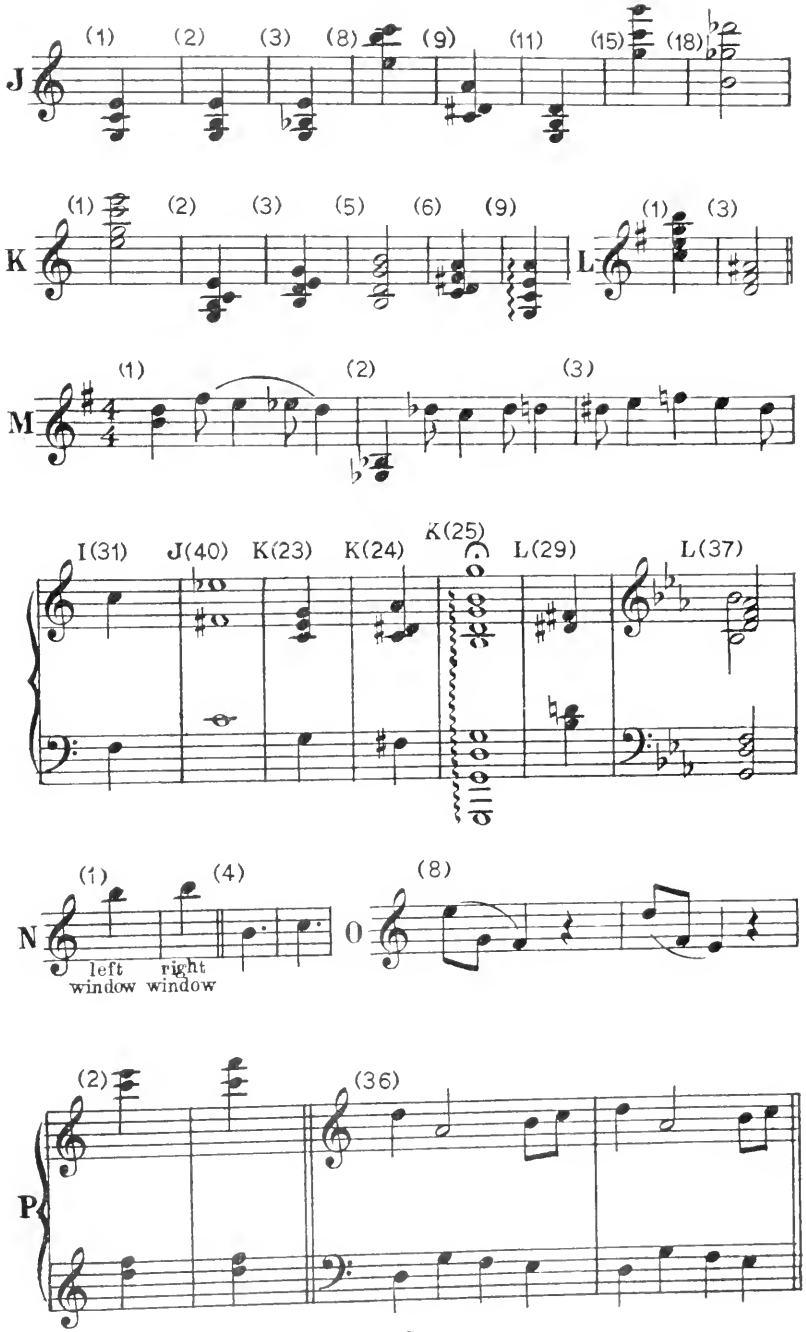


FIG. 2—CONTINUED

Illustrations of the same chord or polyphonic figure played with one hand and later with both hands were scattered through some series for comparison of the difficulty of reading the same music written two ways. Comparison of the success in reading treble for both hands and treble for the right hand with bass for the left was also made with the same patterns, not presented successively, however.

Though many principles were to be illustrated in the selection of stimuli, the writer believed that he had collected enough cards to prove something about each point. More thorough investigation of some of the details would be desirable, however.

3. *The Diagnostic Experiment.*—In order to make a survey of music readers of all degrees of efficiency and with varied background of experience, the experimenter selected 50 individuals to be tested. Of this number 28 were men, 19 were women, and three were children (two boys 10 years old and a girl aged 11 years). The familiarity of these people with printed music ranged all the way from no knowledge of it at all to the keen comprehension of professionals of long years of experience. Many degrees of efficiency in reading music were found at all stages in musical education. As a rule at least an hour was spent in measurement on each person, but in some cases two hours or more were required to diagnose a subject's difficulties and determine to what degree he responded to patterns of notes if at all. In this time the subject read as many cards from each type of material as he could, while the experimenter made a careful record of every error, to be checked later.

A scheme similar to shorthand for recording as nearly as possible the exact location of every error was invented by the experimenter, who found its use a time saver after some practice with it. Since he has absolute pitch and experience in analysis of music by ear, the experimenter found that looking at the keyboard while the subject played was not always necessary. Furthermore the writer had the advantage of knowing thoroughly the music he had selected, while his subjects had never heard any of it. Hence all errors, even playing in the wrong key, registered immediately in the experimenter's consciousness. If the

subject missed the first note on a card, the last, the last two, the highest, the lowest, a sharp, a flat, or the time values, a separate marking in the appropriate place on a prepared data sheet kept a permanent record of the error. If more than two errors were made, only the number of them and whether they were in pitch of the notes or in their time values were recorded. This procedure took little time, even though a large variety of markings was employed. Introspections about particular cards or persistent difficulties were frequently recorded on the back of the data sheets. Later, by looking at each card read, the experimenter could tell from the record of the subject what types of errors were most persistent. He could also calculate the average span of perception for each kind of material read.

When a person was selected for diagnosis, he was given some preliminary trials with the apparatus before any records were taken. During this time he learned where to look for the stimulus and became accustomed to the flash of the card and motion of the disc. He was told the signature, time, and whether the right hand, left hand, or both were to be used. Then the experimenter said, "Ready—go," allowing about a half second between the two signals and releasing the trigger precisely upon saying "go." Not later than a second after the flash, the subject was supposed to play what he saw and to guess if not sure of all of it. Pondering over any pattern or reconstructing it from the afterimage was discouraged, since this method would not be possible in straightforward reading. As soon as the exposure ended, the card was quickly removed, while a pencil was taken up to write the record for that trial. After writing the result, the experimenter swung the weight back for another trial and put in a new card. Immediately a pair of signals was given as before. Steady rhythmic action was kept up to maintain regularity, except when it was interrupted to record introspections. The subject was not told whether any of his responses were right or wrong until an entire series was completed, at which time he was allowed to examine his record.

Conditions were kept reasonably quiet during experimentation. The first part of the work was done at the University of Michigan

in a laboratory that was far removed from almost all noises that could serve as distractions. Later the experiment was set up in a 90 per cent sound proof studio in the Louisiana State University School of Music. Still later it had to be moved to the psychology department of the same institution. Similar conditions prevailed throughout. Good pianos were obtained in all three places and put in excellent condition before work was begun.

Subjects who did not have enough knowledge of music to play the piano were asked to state what line or space the notes were located on, or to draw the pattern on a prepared staff. They were given the comparison cards as the others were, but could not name the notes that were changed. They merely located the changes. The purpose of using nine of these untrained people was to determine whether they saw the notes in patterns, and whether they could reproduce what were for them nonsense visual figures or notice differences in the details of similar ones. All other subjects could at least play the simpler cards.

4. *The Practice Experiment.*—The purpose of this portion of the work was to study the general effects of practice (not on any specific material), on the ability to organize patterns on the stimulus cards presented. Preliminary research indicated that some kind of Gestalt is involved in reading music. Therefore the experimenter felt safe in proceeding on the assumption that a Gestalt interpretation of music reading is possible and might prove useful.

The total number of subjects who practiced was 24, of whom 14 were women, 8 were men, and 2 were high school girls, one aged 13 years and the other 14. With the exception of 3 the ages ranged from the late teens to 30 years. One middle-aged woman was in the group. Nearly all were advanced technically on the piano, and could play material of fourth grade difficulty at least if not more advanced repertoire. Two of this number were not technically efficient enough to make progress beyond a certain point possible, because their response to notes was not sufficiently automatized. These two only practiced 10 hours each. Nine practiced 20 hours, and the remaining 13 did 30 hours of work each. Unfortunately not all of the subjects could

be obtained for as much as 30 hours of work. One in the latter group worked 3 hours beyond the 30 out of her own interest to see if further progress would be possible. The greater number of females could not easily be avoided since comparatively few men study piano in college.

Selection of the individuals for the experiment depended upon their present ability to play and their past training. Ordinarily four years or more of previous piano study proved to be essential, so that the motor response was never too difficult. Some knowledge was obtained about each person's training, efficiency in playing, and accuracy and speed in music reading before the experiment started. Piano teachers furnished this information in most instances, but in addition the experimenter asked the subject to read at the piano, before the tachistoscope was mounted, two selections, the first slow in tempo and the second fast. Piano interludes in "Symphonie Espagnole" by Lalo for violin and piano were used for this purpose, since almost no pianists have ever played it unless they are expert accompanists. A subjective evaluation of the reading of each person was then entered on his data sheet. He was rated in a manner similar to the grading system used in most universities: A, B, C, D, and E with plus or minus signs in a few cases.

Following this test he was given a brief explanation of the apparatus and purpose of the research so far as practical application is concerned. This served to motivate him to put his best effort into the practice. Then he was given a half hour or more of preliminary trials on cards not to be used later. The experimenter showed him where to look for the stimulus, and told him to leave from about a half second to a second of time after the stimulus to place his hands for the notes and then play them promptly without debating mentally whether he was right or wrong. If a finger slipped, the performer might repeat the passage to play what he intended. Under any other conditions, a hesitation would be marked as a mistake in time. The subject was directed to play in strict time at any convenient moderate tempo. Any introspections as to how the reading was done or why it was too difficult were recorded on the back of the data

sheet from time to time throughout practice. Any persistent errors were noticed and recorded as such on the sheet. The preliminary trials made the subject adapted to the experimental situation and the rules of the game before results were taken. A half hour usually fixed the simple habits needed for correct following of instructions. The subject found in this time the distance at which he could read best, which varied individually as it naturally should.

The actual experiment began. Results were treated more in detail than in diagnosis. All cards were given in all series except the last few in F, which were far too difficult for some, and two entire series, G and H, which turned out to be unsuited to tachistoscope work. Cards in other series that were too complicated to be read by most subjects in a short exposure were given anyhow in order to see if part of the material could be read.

Each subject practiced three times a week, an hour at a time, except during the summer session of 1937, in which the limited time made five practice hours a week necessary in order to finish the work before the vacation. No strain was reported by most subjects near the end of an hour, but three suffered occasionally from headaches after the practice hour was over. These individuals needed a change in their glasses, and suffered some eye strain in other activities. Unfortunately a scarcity of qualified subjects made the exclusion of those with serious eye defects impossible, but the writer believes that the effects of this factor were slight. Regularity in attendance was difficult to secure because of illness and the irresponsible attitude of many undergraduate students. Effects of absence from the experiment seemed to be only temporary, however, and a few minutes only were taken to readjust the person fully to the conditions. This irregularity did, however, cut down the number who could be obtained for 30 hours of work.

The rapidity with which the material could be covered varied individually, because some gave more introspections than others concerning how they read, and because some were prompt in response while others were slow and uncertain for hours in spite of their efforts to follow the instructions and react quickly.

Consequently the total amount of material read was not the same for everyone. About five readings of the entire collection of cards could be covered in 30 hours. Some of this time was taken for preliminary instructions and trials, introspections, specific instructions of what signature or clef sign to keep in mind for each series, the final test, etc. No one card was shown to the subject on two successive days. After seeing it once, he did not see the same one again for at least a week, and usually ten days. Consequently memory for any specific material would be expected to be slight. Not even the sequence of the cards was altered.

The subject was not told just what errors he was making, since wrongly read cards might remain in memory better than correct ones, but he was allowed to examine his record briefly after each series. When he saw general improvement on his data sheets, he was motivated to greater effort so that his progress might continue.

In order to check on the practice effects at the end to see whether they were specific or general, a T series was collected for testing. No subject had read the cards of the test during practice. All errors were recorded in order to compare the efficiency on these cards with that on the practice series. Finally the two Lalo selections were presented a second time without the tachistoscope. The subject had not seen these for over two months. Again a subjective evaluation of reading efficiency was entered on the data sheet by the experimenter in terms of the letter ratings described earlier. A comparison of the first and final readings of the two passages was then possible. The number and type of the errors made both times could in some cases be fairly accurately recorded after each reading. If the accuracy was too bad, this was impossible, of course, but some comments on outstanding deficiencies were made in every case.

The writer is fully aware of certain inadequacies in his subjective evaluation test, but he felt that the practicality of the tachistoscope technique needed demonstration to prove that the measured gain in span of perception and accuracy might be applied in the ordinary reading situation.

Following a suggestion given by Dr. W. B. Pillsbury, the

experimenter took a few photographs of eye movements made during the reading of certain types of music which could not be read very well tachistoscopically. Unfortunately no such elaborate equipment as that of Jacobsen was available for this purpose. Therefore the widely used Ophthalmograph was tried. All horizontal movements over a card bearing a simple melodic line could be clearly demonstrated, but vertical and diagonal ones, which would obviously be frequent in any elaborate music, were lost so far as this camera was concerned. The cards used for these photographs were illustrations of polyphonic music to be played on the piano by both hands, therefore the films did not show which melodic line was being fixated at any given moment. Projection of the pictures on the cards so that the image was equal in size to the card photographed gave the number of fixations made, and their location horizontally. The experimenter had no exact means of determining whether the reader was fixating a note in the right hand or one immediately below it in the left hand part, however. In some cases he could guess with fair certainty where the fixation was, but in others he could not. Therefore this approach was a mere side issue, and could not be carried out with success as extensively as desired.

IV. Results

1. *Individual Differences in Span of Perception.*—The fifty individuals who were tested for diagnostic purposes were divided into three groups. The first ten subjects were professional musicians, among whom are listed two outstanding, internationally known concert performers, who are now teachers in two leading universities, and other musicians of high rank. Thirty individuals have been included in the second group, who have had various amounts of musical training all the way from a conservatory diploma to a few months' study of an instrument only. Ten subjects who could not name the notes on the staff with certainty made up the third group in this experiment. Two groups are treated separately in Table 1, in which mean scores

TABLE I

MEAN SPAN OF PERCEPTION AND RANGE

Professional

Subject	Training in Music	Melodic M	Melodic R	Polyphonic M	Polyphonic R	Chords M	Chords R	Type of Reader
1.	Organist	5.3	1–9	5.7	2–8	3.9	2–9	Pattern
2.	Pianist	5.2	2–9	5.8	3–8	3.6	2–9	Pattern
3.	Pianist	5.4	1–9	5.1	2–7	3.6	2–8	Pattern
4.	Violinist	5.1	1–7	5.1	2–7	3.6	2–8	Pattern
5.	Pianist	5.8	2–9	5.6	2–8	3.9	2–9	Pattern
6.	Pianist	3.2	2–7	3.1	1–6	3.1	2–7	Part, fills in subjectively
7.	Violinist	4.8	2–7	5.0	1–7	3.6	2–6	Pattern
8.	Violinist	4.0	2–6	3.9	2–6	3.5	2–5	Pattern
9.	Pianist	5.3	2–9	5.7	2–8	3.9	2 8	Pattern
10.	Violinist	3.1	2–6	4.0	1–6	3.1	2–6	Part, completes subjectively
Mean		4.72		4.9		3.59		

Non-professional

1.	10 years	2.9	1–5	2.1	1–5	3.1	2–4	Part
2.	10 "	2.7	1–4	2.0	1–4	3.2	2–5	Part
3.	9 "	2.9	1–5	3.0	2–5	3.1	2–5	Pattern
4.	9 "	3.8	1–7	3.4	2–5	3.6	2–6	Pattern
5.	9 "	2.1	1–4	2.2	1–4	2.9	2–4	Part
6.	8 "	3.8	2–5	2.9	1–5	3.5	1–6	Pattern
7.	6 "	2.7	1–5	2.1	1–4	3.1	1–5	Part
8.	5 "	2.9	1–5	2.4	1–5	3.6	1–6	Pattern
9.	5 "	3.8	2–7	3.4	2–6	3.6	1–7	Pattern
10.	4 "	2.4	1–4	2.1	1–4	3.0	1–4	Part
11.	4 "	2.5	1–4	2.0	1–4	3.0	1–4	Part
12.	4 "	2.5	1–4	2.0	1–4	3.0	1–4	Part
13.	4 "	3.8	1–5	2.9	1–5	3.7	2–7	Pattern
14.	4 "	2.7	1–4	2.1	1–4	3.0	1–4	Part
15.	4 "	2.9	1–5	2.1	1–4	3.6	1–6	Pattern
16.	3 "	2.7	1–4	2.2	1–4	3.6	1 6	Part
17.	3 "	3.8	1–7	2.4	1–5	3.5	1–6	Pattern
18.	3 "	4.1	1–7	2.9	1–5	3.5	1–6	Pattern
19.	3 "	3.8	1 6	2.4	1–6	3.8	1–6	Pattern
20.	3 "	3.7	1–5	2.4	1–5	3.1	1–5	Pattern
21.	3 "	2.7	1–4	2.1	1–4	3.1	1–5	Part
22.	3 "	2.8	1–5	2.1	1–5	3.1	1–5	Part
23.	3 "	3.1	1–5	2.4	1–5	3.3	1–6	Pattern
24.	3 "	2.3	1–4	2.0	1–4	3.1	1–4	Part
25.	3 "	1.7	1–5	1.2	1–5	2.1	1 3	Part
26.	2 "	1.6	1–4	1.0	1–3	2.1	1 4	Part
27.	1 year	1.2	1–3	1.4	1 3	2.3	1 4	Part
28.	1 "	1.5	1–3	1.0	1–2	2.1	1 3	Part
29.	1 "	1.1	1–3	1.2	1–3	2.0	1 3	Part
30.	6 months	1.4	1–3	1.1	1–2	1.9	1 3	Part
Mean		2.73		2.15		3.06		

are given for each person for the three types of material used in the test. The scores represent the number of notes that could be read at one exposure. Naturally the range of these scores was wide, because some patterns were of greater complexity than others. Many factors operated in determining the number of notes that would be accurately perceived on each card. The area covered by the group of notes made a difference, naturally, since the notes that did not fall on or near the fovea were illegible. Hence, within limits, the closer the notes were crowded together, the more of them were seen at an exposure. Wide spacing has been used for quarter notes and narrower spacing for eighths or sixteenths in nearly all printed music for the simple reason that experience has proved that we can read them more easily this way. Faster notes must be seen in larger groups than the slower ones in a melody.

The mean scores for melodic material given in Table 1, therefore, were based on reading of close spaced groupings in every case, in order to make the conditions as uniform as possible for all individuals tested. The polyphonic material used in the test was two-part music for one hand, since music on two staves was impossible for the majority at that short exposure. The chords included in the test were in half of the examples on one staff, and in the other half on two staves. Since there was a wide variation in span of perception, some subjects had to be tested on three note groups, others on four, and still others on six. If all subjects had been given six note cards, confusion might have resulted when the less advanced performers attempted to get all that was there.

The range of the numbers of notes seen is given to show that some patterns were almost impossible without analysis, while others were so familiar that only a few cues were necessary to call out the complete response. Errors caused by looking too high or too low, etc., were not included in calculation of the span if discovered. Usually no notes were correct if this happened, and the observer was given another chance. Table 1 includes the subjects who could play at least the simple cards. Ten others were treated separately.

(a) *Totally untrained subjects:*

1. This individual could read only one note at a time with certainty as to its location. If given a melodic progression of two notes, he could tell in which space or on which line one note was located, but failed over 50 per cent of the time with the other note. In locating two notes on the staff on Series I, he scored 90 per cent success, but failed almost entirely to locate three note chords. The comparison technique applied to this individual gave about the same result as the description of location. The subject reported that he did not see the notes in groups.

2. The result was practically the same as for the preceding subject except that if two notes were on adjacent steps in melodic progression, she described their location correctly in the five cases of this kind. She reported that she picked out single notes, and could not describe the shape of patterns.

3. This individual reported that he could see configurations vaguely, but could not locate them on the staff, which he could not see as clearly as the notes. Comparison cards showed him to be very uncertain of the differences in details of even the simplest patterns.

4. This subject scored only 60 per cent success in locating one note on the staff. He reported that he did not see groups of notes as wholes, but attempted to pick out one note.

5. Though he could not play or name notes rapidly at all, this man has sung by ear, being guided by note position. He made a mean score of 1.5 notes for melodies and 2.0 for chords, telling promptly the exact location of the notes he saw clearly. In larger configurations he observed direction of motion only, and could not give details.

6. The response was inaccurate even if only one note was shown, but the subject occasionally located three notes correctly on the staff. He claimed to see the group as a whole in the cases in which he succeeded, but he failed in over 50 per cent of the trials.

7. The report was similar to subject 6, except that in this case the accuracy of location for chords was greater than that for melodies.

8. This subject saw groups of three notes as wholes, according to his report, but had difficulty in seeing the lines of the staff. Therefore his descriptions of the location of the notes were frequently wrong because he placed the entire pattern too high or too low by one line or one space, even though he grasped the relative position of the notes accurately. He located one note correctly 90 per cent of the time, but his failures greatly increased if two notes were shown.

9. This subject scored higher on chords than on melodies. His mean on the former was two notes, and on the latter 1.5 notes. He could not give details of the patterns of three notes or more.

10. The report was identical with subject 9.

An examination of Table 1 reveals the fact that in general the greater the amount of training, the better is the reading of these cards. There are a few noteworthy exceptions that will be discussed later. Polyphonic music naturally confuses those who have not had sufficient training to have mastered its difficult points through experience in playing it. The years of training in the second group are the number of years of piano study. Public school music was not counted, nor was voice training, of which four subjects had a little. The last column contains information as to whether the subject usually grasps a group of three or more notes as a pattern, or whether he sees only one or two single notes which serve as cues, and completes the group subjectively. This fact was brought to light not by introspection alone, but chiefly by the nature of the response and the errors made. Those who reported that their impression was of the whole responded, with but few exceptions, without hesitation a brief fraction of a second after the exposure. If they made mistakes, these were generally errors of locating the entire group too high or too low on the staff. Those who reported that they saw only one or two notes clearly demonstrated the fact that they had no idea of the shape of the pattern in that they usually got one note right, but merely guessed at the rest. Working out the part that was illegible to them by logic took at least a second after the

exposure, often much more time. When the response finally occurred, there was a noticeable uncertainty about it in contrast to the prompt, self-confident response of the pattern readers.

Naturally the line of distinction between part and pattern readers is difficult to draw in some instances. For the very best subjects some patterns were impossible to grasp. Only parts of these were seen, and completion had to be subjective. The slowest readers rarely see whole groups, but exceptions to their part method do occur if the groupings are easy. Therefore the pattern response to notes seems to be a matter of degree, and our distinction here is arbitrary perhaps, but it may prove practical. At least it is closely analogous to Dearborn's A and B classifications referred to in Chapter II. Whether anything corresponding to Dearborn's C group occurred in this experiment is as yet unknown to the writer. Further research may clarify this point.

Subjects who have studied harmony and counterpoint extensively scored higher, as a whole, than those who had studied only an instrument, but here again there were noteworthy exceptions. Men did not do significantly better than women, though not enough subjects were used to determine whether a small, but reliable difference does exist. Experience in playing the music of Bach invariably raised the efficiency in reading the polyphonic selections from this composer, even though none of the subjects were familiar with the selections to be read. Experience with ultra-modern music aided, as might be expected, in the recognition of certain chords used in this experiment which others not having such experience failed to get.

(b) A consideration of the individual results of *professionals in the first group* might be of interest. Subject 1, a concert organist and teacher of high rank, is noted for his facility in reading the most intricate passages for organ or piano almost without error the first time. The rapidity with which he takes in three or four melodic lines in reading a fugue or chords in even a quite unconventional progression has amazed many of his colleagues. He averaged above five notes on melodic and polyphonic material in span of perception, but was not as high on chords because most of the examples of this type contained only

four notes or less. His response was made less than half a second after the exposure in all but two cases. He found card B 1 puzzling (see Fig. 2), and saw only the first note. He read six note groups in series D without difficulty in estimating the wide intervals, unlike less experienced readers. He responded to 9 notes of D 43, but did not see the last 3 notes. Examination of this card (Fig. 2) will reveal that mere surmising was highly improbable in this case. He reported that he got only a few essential cues in reading K 25, in which he read all of the nine notes correctly. His introspection follows: "That time I did not see all the notes clearly. I saw the general form of it—that it was a G major chord, you see, and then, just by their distribution, I guessed what the rest were most likely to be, and happened to get them right."

Because of his interest in modern idioms, this organist read the chords in the latter part of L correctly, using their general form as a cue to recognition. Few can achieve this. He reported that in Series F he encountered several forms that did not register, while others were comparatively easy to grasp. His errors as well as his introspections revealed the fact that he nearly always used the general form as a cue to aid him in recognition. He pictured E 1 as a scale, for example, D 4 as a broken G minor chord, F 25 as an ascending passage of thirds, L 3 as an augmented triad, etc. He did not seem to start at the bottom and read up, or even to do the reverse, but in most cases saw the whole at a glance even if it was on two staves.

Subject 2 in the professional group was also noted for efficient reading. She is an internationally known concert pianist. Her reading seemed to be definitely by general form, though she was not clearly conscious of how she achieved it. Card B 1 also gave her difficulty, while the six note groupings came easily, with a few exceptions. The first two subjects found exactly the same cards to be the most difficult.

The third performer, a pianist, also used the form as a cue to recognition, but was not quite as prompt in responding as the first two. Though technically efficient and gifted in music, he is known to be less accurate than the first two subjects in sight

reading. The difference is not great, however. He tended to depart from his usual procedure in response to modern idioms. He could not integrate unusual chord patterns well, and tended to work them out by logic from a few cues, making them conform to some conventional chord pattern closely resembling the chord presented to him. His reaction time exceeded two seconds on many of these, indicating a possibility that he deciphered such combinations from a clear photographic memory of them. He was rarely conscious of such a procedure. He reported that the presence of fingering marked on the music frequently helped him to get the notes. All other subjects appeared to ignore the presence of these markings when reading, and some reported that they never saw any. Only one was distracted by the presence of fingerings.

Number 4 is a concert violinist internationally known, and also a teacher of violin. He plays the piano, but not as efficiently as the three preceding people. One might expect him to be higher in mean score on melodies than pianists, and comparatively less efficient on chords, but this is not the case, as can be observed from Table 1. He is an efficient reader, even of the most difficult material for his own instrument. Some of his introspection on what his difficulties were read as follows: "I can see the notes all right if they are solid, like quarter notes, but if they are open notes, they are not as plain. Also I notice I have trouble seeing the staff. The lines are not plain to me like the notes are. Sometimes I don't see any lines." He frequently expressed surprise at an unexpected change in position of the notes from one card to the next. He complained that many of his errors were the result of having no chance to anticipate what was coming next. This complaint was quite common, and it brings out one essential difference between the experimental situation and uninterrupted reading. He appears to use general form as a cue, but is unconscious of the details of his procedure.

Subject 6 is an efficient teacher of piano and a fair performer, but a slow, stumbling reader in spite of extensive training. Her responses show that she did not notice the general form of a group of notes, but saw only two notes clearly. She was clever

at finishing patterns subjectively, and frequently succeeded, but occasionally revealed the fact that the subjective was playing a larger part than it should. Her reaction time was frequently two seconds or more, and her response was likely to be hesitating unless the material was easy. Wide skips bothered her in A 5, A 37, C 4, and C 7 (see Fig. 2). She tended to underestimate these intervals.

Nothing particularly striking was found in the records of the next two subjects, except that they had the greatest difficult with the same cards that troubled all of the others.

Three musicians of the professional group, 6, 8, and 10, could not read both hands in Series J, K, or L with greater than 40 per cent success. They could get one hand or the other in a chord, but looking midway between often resulted in missing both parts. The others saw all the notes clearly on both staves if they were not spread out over too much space. Universal difficulty was experienced in perceiving two-part polyphonic music for both hands at a short exposure. Probably jumping back and forth is necessary, and the maximum number of notes per fixation of the eyes is three in this kind of music as a rule. Few exceptions occurred, and doubtless the tachistoscope is inadequate to measure performance on polyphonic material for both hands. However, the experimenter found his results interesting and worth while on polyphonic music.

(c) A survey of the results in the *non-professional group* reveals the fact that at all stages in musical education one can find inefficient readers and skillful ones. Talent appears to have little to do with it, since teachers often report that some of their most promising pupils are unable to make much progress in reading, while others read well, but have different limitations. A few examples will illustrate special disabilities.

Subject 1 is a fair performer on the piano, but reads slowly. Her accuracy was fair on the test, but her span of perception was limited. She was inclined to ponder over a stimulus card five seconds while looking at the floor. Then she played two, or rarely three notes with self-confidence, as if she was certain of the response. She was sure that she was right, and usually

she was correct as far as she went, but if the pattern included more than two or three notes, she was unable to obtain any accurate impression even of the direction of motion of the rest of the notes. There was no evidence of any anticipation in her reading, and her thought processes were slow in reading music in spite of thorough theoretical and practical training. She was greatly confused by polyphonic music, even on the same staff, and could not read chords for both hands at a single exposure. This case is an example of a limited span of perception together with slow habits of thinking, an over-careful attitude, and too many inhibitions.

Number 4 is an example of a good reader, who plays well. He reads by patterns and responds quickly as a rule, but he has some individual limitations. Wide intervals bothered him. Any skip of more than a fifth in a melodic pattern caused inhibition of his usual prompt response. After two seconds or more he either played something to represent the shape of the general configuration, missing some notes by one step usually, or else remarked, "I've lost it now." He was inclined to overestimate wide skips by one or two steps. He grasped large units of material of a conventional sort, but failed miserably with ultra-modern chords, because of his lack of experience with that type of music. He tended to make these conform to conventional chord patterns, frequently admitting that his response was a mere guess. He said that these peculiar chords did not make sense to him as the conventional ones did. His record clearly showed that major, minor, augmented, and diminished triads in any inversion or position were meaningful units to him as were also most seventh chords unless altered. Ninth, eleventh, and thirteenth chords were usually spelled out one note at a time mentally. When he finally played what he had figured out, it was usually less than half right.

Not much difference was found between the results of the typical professional musician in the first group and the record of subject 13 in the second group, who reads exceptionally well, even though he has studied only four years. He plays mechanically, without much interpretation, and does not consider himself

musical. He has little theoretical knowledge of music, and his piano teacher did not consider him talented. He can read the correct notes in time of almost any composition within the limits of his technical ability, even in the realm of the ultra-modern to some extent, though he claims that such music does not make sense to him. His correct readings of unusual chords were more frequent than one would expect, considering his limited training, because most of the subjects of his degree of advancement did not read this type of material in patterns. They picked out a few cues and almost always failed. The writer does not know of a satisfactory explanation for this exceptional case. As a general rule, experience with a given type of material increases the span of perception for it, but this subject had not played polyphonic or modern works one-tenth as much as many more advanced performers, yet he excelled them in reading both types. He did not remember anything in his musical training which would have caused him to form the habit of grasping tone groups. As far as he knew this habit came about by mere accident.

Table 1 does not show some of the changes that were evident in the performance as those of lower and lower degrees of advancement were tested. Beginning with the students of four years and increasing as the amount of training decreased was a tendency to count leger lines above or below the staff instead of responding immediately to music so located. Professionals and most of the advanced students are usually able to read notes not more than three leger lines above or below the staff without counting these lines, but the less advanced failed on numerous cards because they lost the impression while trying to count. Occasionally clear imagery aided in retention of the visual pattern until a response could be counted or reasoned out. Subjects 16 and 19 showed evidence of photographic memories, which made up for the lack of automatization of their responses to the printed notes by playing them upon the piano. Number 19 was skillful with his fingers, but had played so much by ear and so little from the page that he was slow in deciding what a note was, even though he retained a clear impression of its location

on the staff. Subject 16 reported that she was always puzzled when she saw accidentals, and had to stop to think them out.

Among those of two or three years' training, there were several whose excessive playing by ear resulted in a lack of automatization of response to individual notes. Number 24 had difficulty in finding notes on the bass staff, because she was more familiar with the treble staff on which all the notes she sang were written. She was in the habit of guessing the bass, not really reading it, because she could figure it out by ear in simple music by finding what would sound best with the treble. Even the beginner does much surmising in reading music, as he does in reading words, but he is not as successful with his subjective completions as is the more experienced performer.

Examination of the table of results for the professional group will reveal that the average span of perception is greatest for polyphonic music, slightly less for melodic examples, and considerably less for chords. There are small individual differences in the proportions of these figures, but the general rule holds good that fewer notes were correctly perceived in the harmonic material. The cause of this lies partly in the difficulty of reading on two staves at once, one usually being bass and the other treble. Most of the polyphonic and all of the melodic examples were on one staff. However, it is interesting to note that in the second group the mean scores of all 30 subjects are reversed. Chords now rank highest, while melodies come second and polyphonic cards third. It is easy to understand why the polyphonic type is extremely difficult for those with less training. Success with it falls down more than that for other types as one reads down the table. However, it is more difficult to discover why the chords are easier to read than the melodies for many of the less efficient readers. The explanation may be partly in the nature of the particular examples used in the test. Some of the notes in the chords were crowded together more closely than any of the notes in the melodies. Most of the three-note chords were on one staff. The four-note examples often had three notes on one staff, or even all four in a few cases. Therefore for pur-

poses of comparison, the number of correct readings of D F A written as a chord on the treble staff was checked against the number of successes with the same notes given in melodic succession on the treble staff. Out of 40 readings of each, there were 29 successes with the melody and 36 with the chord. All four of the subjects who failed to read the latter correctly missed the former also. The most common error with the chord was to play it one space too high, that is to say F A C instead of D F A. The most common error with the melody was to mistake it for a stepwise progression, D E F, a sign of extremely inaccurate observation of details. There were three subjects who played D F G, which indicates that the last note probably lay outside the field of clearest vision, or else was forgotten while the first two were being figured out.

Other examples were compared to check on this point further. The fact that successions of two or three notes were more difficult than the same notes written under each other in the form of a chord was illustrated in 8 examples. Thirty subjects who read these examples averaged 7.8 right for the chords and 6.2 for the corresponding melodic patterns. Individual differences were not very great, and the same tendencies to error were universal. In the case of the chords, the subjects tended to get the relative position of the notes with respect to each other quite accurately, but failed to place the pattern correctly on the staff in a few cases. They reported in their introspections that they saw one-hand chords plainly, every note being as clear as every other note usually. Exceptions to this were rather rare. However, they reported that their difficulty was chiefly in determining which lines or spaces the chord occupied. One of them, who was well acquainted with psychology, expressed his view as follows: "The notes stand out, but the staff is not a part of the figure. It is background to me, and not noticed so much. The notes attract my attention, but the staff does not. It seems to me that there is a figure-ground distinction there in which the staff is ground." Following this up, the experimenter questioned two others acquainted with the Gestalt concept of figure and ground, and for them the staff was a part of the figure.

The outstanding tendency in the corresponding melodic phrases was to miss the last note by placing it too high or too low by one step, or more rarely by two steps. The probable cause of this error was failure to see this last note clearly, since the introspection indicated that the first note or two notes appeared to be much plainer than the last note in many cases.

Another factor that is of importance in the span of perception is the area covered by the pattern. The horizontal distance along the staff over which notes were clear enough to be legible was roughly determined from the results. Since ordinarily most errors occurred at the end of a group, the experimenter could measure the length of the part accurately read on cards on which correct guessing was unlikely. From this he could determine with fair accuracy the width of the legible portion of the field. This distance, which was calculated for every subject from five cards, ranged from about $\frac{3}{8}$ inch to $1\frac{3}{4}$ inches, and the mean was approximately $\frac{7}{8}$ inches. The vertical distance over which chords were legible was similarly estimated. The figures ranged from about $\frac{3}{8}$ inch to $1\frac{1}{4}$ inches, but the mean was again approximately $\frac{7}{8}$ inch. Unfortunately the distance of the card from the eyes was not recorded, but observation indicated that those who set closer to the apparatus than the average covered a smaller area than the ones who sat farther back, as might be expected. Nevertheless under the conditions of this experiment, any change from the accustomed reading distance of each subject was not advisable, especially for those who practiced reading with the tachistoscope for many hours, because such a change would result in eye strain and decreased clearness for many people.

2. *Analysis of Individual Difficulties.*—We turn now to a consideration of the more thorough study made of 24 individuals not included in the groups discussed in the previous section. As stated in the description of the practice experiment in Chapter III, these people were given all of the material to read except that which proved entirely too difficult for them. They constitute the practice group.

The knowledge that could be obtained about their individual

disabilities was much more extensive than that from the diagnostic group, although none of the results conflicted on any important point. There were several difficulties that were common to a majority of the subjects as they went through the various series, and these will be discussed first.

Twelve subjects claimed that although the manuscript cards were plainly written, small irregularities made them more difficult to read than printed notes, although the difference in difficulty was small. The remaining number did not notice any difference. The record for the entire group for Series A, which was in manuscript, indicated little loss of accuracy for this reason. The wide skips of a sixth or more were more frequently missed than the smaller intervals, *i.e.*, fourths, thirds, and seconds. Octaves were more easily perceived than sixths, sevenths, and ninths. The latter were frequently mistaken for the former by considerably over half of the subjects. The introspections that were recorded on the difficulty with wide intervals indicated that usually one or the other of the notes was not seen clearly, which suggests that possibly in uninterrupted reading these combinations are read with two fixations of the eyes, one for each note.

Series B, in the first half, gave all subjects persistent trouble, because at that short exposure they could not grasp the time relations on some of the cards. Eighth notes, unless connected together by a bar, were unobserved on a number of cards and played as quarters by 14 subjects. The remaining 10 seldom had this difficulty but they occasionally failed to observe which notes were eighths and which were quarters. The frequent failures on the last note were caused by the fact that the distance covered by many of the patterns was too great to be seen clearly at a glance. The clearness with which the notes in the last part of Series B were seen was more nearly equal for the three notes, because they were confined to a small area. Therefore few failures on the last note occurred. Nearly all subjects made occasional misplacements of entire patterns on the staff. The less efficient readers in the group, who numbered eleven, frequently played B 21 as B C ♮ D instead of B D F ♮, showing that they observed only the first note and the direction of motion

of this group. Seven of these played B 22 as G F ♯ E, showing a similar inaccuracy in observing details. These and other errors of the same kind persisted for three subjects through two or more trials, but for the others accuracy increased with practice, eliminating this difficulty by the second trial. There were two or more instances of failure to remember the signature of the last part of Series B on the records of thirteen observers.

The records on Series C showed that complexity varied not only with the number of notes in a given pattern, but with various optical and musical factors. Some cards were difficult for everybody, while others gave trouble for comparatively few. For example C 3 was persistently missed by only 2 subjects, while C 4, C 7, and C 19 caused some failures on every record (see Fig. 2). The distinction between the easy and difficult patterns, from these and other examples, was found to depend upon the width of the intervals between tones, the consonant or dissonant effect of the intervals, and position on, above, or below the staff. The wider the skips, other things equal, the greater were the chances of failure. Observers tended to make note groups conform to a chord or scale pattern, and end in such a way as to produce a pleasant effect. As mentioned before, the use of leger lines, as in C 19, resulted in counting, and consequent loss of the impression.

For similar reasons there was a gradation of difficulties in Series D. With these longer groups, a possible subdivision, on the basis of arrangement of the elements, into two groups of three, or more rarely three groups of two, greatly facilitated the response. Such was the case in D 1, 2, and 3, but not 12, for example. D 4 was easy because it followed a familiar broken chord pattern, but D 12 was impossible for most subjects to grasp at all.

Frequent modulations in Series D caused a greater number of failures to remember the one flat in the signature than might be expected. Fifteen observers failed persistently in this respect until near the end of their practice. The four sharps in the signature from D 41 on caused some failures for 16 subjects. As a general rule the less highly trained individuals had the

greatest difficulty keeping signatures in mind. The added difficulty of the presence of more notes than could possibly be seen clearly at a glance caused forgetting of sharps in the signature as well as confusion with regard to time values. The part readers were invariably confused, and played one or two notes or failed to respond at all. They had no clear idea of the direction of the progression, even if they had played the first two notes correctly. The pattern readers in the group grasped 3, 4, or more notes, usually the first part of what was on the card. The four best readers were able in addition to get the direction of motion of the rest of the material on the card. They often failed to observe the exact notes on the part vaguely seen, but they could indicate by their responses that they were looking ahead and anticipating what was to come next in order to prepare for it. For example these best readers gave an accurate rendition of the first five notes of D 41, but only vaguely anticipated the last six notes. They knew that these ran up, but how far they did not know. Two of them saw that these were sixteenth notes going up the scale, but nothing more definite about them than that. The irregularity in the middle of the progression on card D 43 was either unobserved or, in a few cases, seen too vaguely to be attempted.

The arrangement of E 1, 2, 6, and 7 (see Fig. 2) is such that a greater number of notes may be included in the span of perception than in Series D. Obviously accurate perception of details is not so necessary where irregularities are absent. Ten subjects persisted in playing one or two notes too many on each card. Eleven frequently misplaced the entire progression one space or one line too high or too low. E 9 was persistently played wrong by 20 subjects. The most usual mistake was to play five notes in each group: G A B C D, failing to observe that one step was skipped. Another common error was to skip the wrong step, for example G A C D. The E flat on card 24 was unobserved by 12 subjects, who persistently played the two groups alike. E 25 was similarly mistaken for two identical groups, but E 26 was played, with but one exception, with the second group unlike the first, but seldom correct.

Polyphonic music for one hand was more difficult than a single melodic line, but two independent melodies in conventional counterpoint were read simultaneously by efficient readers. Errors in the lower part were nearly twice as numerous as those in the upper part. Introspections showed that most observers regarded the lower melodic line as subordinate, and of lesser importance than the top line. Parallel motion was more easily grasped than contrary motion of the parts, and like time values were nearly always played in time, while two notes of one part against one of the other caused considerable confusion. Memory for the four sharps failed persistently in nine subjects. Card F 27 was missed entirely three times as often, approximately, as F 25, because of the fact that consecutive fourths were comparatively rare in the playing experience of nearly all subjects.

The result of attempts to read two-part material simultaneously for both hands was a large percentage of failures. Jacobsen's results indicated that this kind of material is not read by a series of units taking in both hands at once, but that shifts of the eye must be made from one staff to the other. The best subjects in this research, however, were able to read simple cards of this sort fairly accurately in the tachistoscope at a glance. Whether or not their usual continuous reading involved such a procedure, taking in patterns including both hands at once, was unknown to these individuals. Therefore a series of eye-movement photographs taken as described in Chapter III helped to clear up this point.

The results of the projection of these films upon the cards read gave the number and approximate location of the successive fixations of the eyes made in reading the card. Figure 3 shows diagrammatically the manner in which a few patterns were read. The location vertically of the pauses was uncertain in a few instances. The writer may not have guessed right in these cases as to whether the subject was fixating the left hand part first and then the right hand just above it or the reverse. Occasionally the horizontal location of the fixations and of groups of notes offered helpful clues, but the writer does not consider these results to be sufficiently accurate to warrant further study of eye-move-

ment records without more adequate apparatus for the purpose. These few diagrams demonstrate conclusively, however, that the readers who were tested frequently shifted their gaze from one staff to the other, taking in a note or a little group of notes at each fixation. They were able to take in two-hand combinations at a glance when these were simple, but did not follow such a procedure in continuous reading of the same material.

A few more photographs were taken besides the ones represented in Figure 3. They demonstrated a similarity in the procedure of E and that of W, both of whom are good readers, in reading the same material. However, results on a third subject, who was a slow and stumbling reader, were too complicated to make accurate locations of his fixations possible without better apparatus. The behavior of his eyes gave evidence of unsystematic procedure, however. There were many regressions on the film, and twice as many fixations as were made by either E or W.

The results on chord reading indicated that the most efficient readers do not spell out a chord, but read it as a whole, unless it is too complicated. A chord that is spread out often covers too great a vertical distance to be perceived without shifting the eyes, and in such a case only the part for one hand is seen as a pattern. Which part will be seen in the tachistoscope in such cases depends upon the direction in which the subject happens to be looking. Under usual conditions, however, the good reader was able to read two-hand chords accurately at a glance. Whether or not this is the procedure in continuous reading remains to be seen. The subjects themselves are uncertain about whether they read chords up or down. Five of them reported that they did not read chords up or down any more than they read single words to the right or to the left, but that they grasped the entire unit almost instantly in most cases. Their accuracy on the harmonic material in this research indicated that their statements were probably correct.

Ten of the less efficient readers reported that sometimes they read chords up and sometimes down. Four of the most advanced players among the part readers gave clear evidence of spelling

chords up, while two beginners gave equally good evidence of always spelling them down, beginning with the highest note in the right hand. The remainder were irregular, and used no consistent procedure.

Checking the comparison series against the other technique for each kind of material proved that if an observer could give the exact differences between details of similar patterns, he was accurate enough in his perception to reproduce the music on the piano, and in only two cases was this reproduction response so difficult as to cause the performer to make errors frequently and become confused by factors other than perception of what was on the card. In other words the level of difficulty of material that could be done accurately was, in all cases but these two, the same for the one mode of response as it was for the other. The response of playing the cards was reported by nearly all as being always easy. If they saw what was there, they could play it as easily as they could pronounce a word or a phrase. Playing the music gave the experimenter a more thorough record of the perception of all details of every pattern than comparison reports of *alike* or *different* and one detail of difference in the case of unlike stimuli. Description of what was seen on the cards was given after the judgment of *alike* or *different*, following the suggestion of Wertheimer, but this description proved more difficult than piano playing for most subjects, because during the slow process of telling the experimenter every note, the last part of the pattern was lost before the subject had finished describing the first part, or one stimulus was forgotten while describing the other.

An example of a typical comparison response will make this clear. The exact words of subject N were taken down as she responded to a card in Series N as follows: "They were different. The first was E, then E an octave higher, and C and A, and the second was—Oh! I had it a minute ago, but I can't remember. Anyway there was a difference near the first." She demonstrated greater efficiency at the piano, since she could respond before the memory impression was lost.

Another difficulty that was common in the comparisons was the fact that frequently the subject would fixate higher in one

window than he did in the other, thus receiving the impression of a difference in position on the staff when no such difference existed.

Material for one hand was easily read, but two-hand combinations were more difficult to describe than to play. Differences were not accurately located by any but the five best readers, but some of the less efficient readers could get vague impressions that these patterns were alike or different without getting very many details clearly. With this type of material as in the preceding there were patterns which seemed impossible to integrate, and others which were easy.

There are a number of individual records which deserve analysis in order to demonstrate the effects of training under different teachers upon reading. Subject A (see Table 2) is a violinist who has considerable technical ability, and has studied extensively both theoretical and practical music, but she spelled out her music one or two notes at a time. Her accuracy was fair at this slow rate, however. She did not stop to think before responding as a rule, but read only a few notes of a pattern, usually two, and guessed the remainder, which she admitted she did not see at all. She was most likely to see the first part of a pattern and have no idea of the shape of the whole, and frequently she got only one or two notes in the middle, and made errors on the first and last parts. She was persistent in this analytical approach, but finally became a pattern reader. She was not troubled by key signatures or by time values. For a person as well acquainted with harmony and counterpoint as she was, the number of correct anticipations of material not clearly seen was surprisingly small. This was true in several cases, suggesting that even with the most conventional type of material, guessing is not likely to be successful. She had difficulty with the lower melodic line in the two-part polyphonic material. She seemed unable to perceive immediately how the two melodies fit together. Therefore she played the upper one, and filled in a few notes of the lower. If the two parts were not on the same staff, she saw one or the other. The ultra-modern chords were not integrated well as wholes even after much practice, but were usually made

to conform to some chord that sounded more consonant in effect. The delay in the reaction was more than two seconds in these cases.

Subject G had the peculiar habit of perceiving the notes first and then looking back to get the accidentals afterwards. Sharps or flats in the signature were carried along as a part of the pattern, and were seldom forgotten, but added sharps, flats or naturals were often overlooked completely. When asked concerning them, she replied that she did not see any or that she saw a sharp or a flat, or something somewhere, but was not sure what it was or where it was located. In such cases her observation of the notes was usually accurate, even if there were six of them in a difficult arrangement. She reported that she did not know why she did not see the accidentals as a part of the pattern, but she knew that she added them on afterwards. She had no idea of the origin of this bad habit. Her reaction to simple cards, which was usually immediate, was delayed two seconds by the presence of one sharp or flat. When the response finally occurred, it was usually correct, unless the accidental was placed on the wrong note. Two accidentals frequently caused complete confusion. The reading of ultra-modern chords was much more difficult for this subject than the reading of conventional chords because of her failure to grasp accidentals with the pattern, though her perception of the notes was usually correct for both hands. Nothing in her past training, as far as the experimenter can find out, could account for her difficulty, since her experience with all types of music has been more extensive than that of others who experienced no such trouble.

Subject H has studied extensively under well known teachers. He is considered gifted, performs well, and has a phenomenal memory. He has memorized everything with great ease since childhood, covering a broad variety of repertoire including many contemporary works. He spelled out his music with accuracy, but slowly and never in time before he began tachistoscope practice. His teachers attempted to rid him of his disability by making him play a large amount of easy new music daily. This had practically no effect. His reaction time with the material of

this experiment was typically slightly over two seconds. Constant repetition of directions to play up to the given tempo was necessary. Hesitations were frequent. Sharps, flats, and naturals were confused and misplaced. He could not read a chord for both hands at a glance with certainty, but he did much intelligent guessing, some of which served to improve his record. The number of cues he actually perceived was too small. His recognition of time values was very poor. He showed no evidence of anticipating what was ahead. A quotation from his introspections, which might be of interest, is as follows. "If I once hear how it sounds, I can play it on the piano easily, but when I see those notes up there, I have to stop to think how they would sound before I know what to do with them. That is because I played by ear too much I suppose, especially when I was younger. Now I am trying to play by note, and I see how much I depended upon my memory before."

Subject R is a child prodigy of fourteen, who plays an extensive repertoire of medium difficulty or better from memory with finished technique and artistic interpretation. She is considered gifted by recognized teachers. Her record is not consistently good, because of unavoidable distractability and lapses of attention at times. When motivated to her best, this child read some patterns of fair complexity, but the number of patterns that failed to register as wholes was greater than that for more mature subjects. Her procedure in reading might be described as unsystematic, and her results were inconsistent. She failed most on modern idioms, with which she was totally unfamiliar.

Subject W is not musically inclined. His teacher did not consider him gifted, and he had no great liking for music, but he studied the mechanics of piano playing until he could play material of fourth-grade difficulty skillfully, but with little expression. His reading is phenomenal for a person of so little musical training. He read polyphonic material with amazing accuracy, considering his extremely limited experience with it, and ultra-modern chords which had to be spelled out by many more advanced performers registered in his experience immediately as wholes. The reason for his efficient reading could not

be discovered by questioning him about his training. He had none of the inhibitions in reading that were characteristic of many other subjects. He was dependent upon the printed page whenever he played, and could do little without it. This constant performing from the page was characteristic of the best readers among the subjects, with a few exceptions, and the majority of the less efficient readers memorized with ease. However, the writer finds insufficient evidence that an inadequate musical memory insures good reading, or that the performer who memorizes quickly necessarily reads badly.

Subject X shows clear indications of an emotional complex centered around practicing from the printed music. She was forced when a child to study piano with a severe and exacting teacher, who scolded her endlessly for every wrong note that she played, pointing out the correct note on the page. The pupil hated this teacher, and also printed music, which in her mind was associated with the teacher, but she enjoyed playing by ear and listening to good performers other than her teacher. She reported that the mere sight of a sharp, the cause of her most frequent errors at lessons, aroused extremely unpleasant emotions, even years after the lessons had ceased. Confronted with the task of overcoming many inhibitions in her reading in order that she might continue her study, she was motivated to work hard on this experiment, but the habits were persistent. Prompt response was blocked by a constant fear of making errors. Indecision on the simplest material resulted in loss of the impression because of delay. Much work was done before any patterns could be perceived clearly enough to play details accurately. Response to single notes was not well automatized, but this factor was a minor one in her case.

Thus it is evident that the individual background of every observer affected his results in an interesting way. These selected examples demonstrate the variety of music-reading disabilities, and the complexity of such a process when subjected to detailed analysis.

3. *Improvement With Practice.*—The mean span of perception is based on more data in this experiment than in the diagnostic

group, but the manner of calculating it was essentially the same. It represents the maximum number of notes that can usually be read by the subject with each kind of material. The range merely indicates the variation in difficulty of the music. Some patterns are impossible to integrate for most subjects, while other relatively long ones are easily read as wholes. The experimenter realizes the incompleteness of his tables, but in attempting to make the results concise and meaningful, he found elimination of minor details necessary. The most important of these details will be treated in the discussion later. The subjects are listed in order of their musical training on their major instrument (not always piano). Degrees are also indicated.

The subjective evaluation of continuous reading of each subject, which the experimenter made before and after practice, is recorded in terms of letters, as stated in Chapter III. The letters correspond to the typical college grading system, but the standards of performance for each letter were the same for everyone regardless of the amount of training or musical experience. Some attempt was also made to evaluate the piano-playing ability of each subject.

Only trials that were complete enough for accurate measurement were included in the table. If the last trial was only half completed, no computations from it were made. Limitations of the time that some subjects would work made equalization of the number of trials impossible.

Under *time* the experimenter placed the per cent of the total number of cards played correctly as to time values. Since only a limited number of cards were difficult in this respect, the percentages were fairly high. Hesitations were counted as time errors.

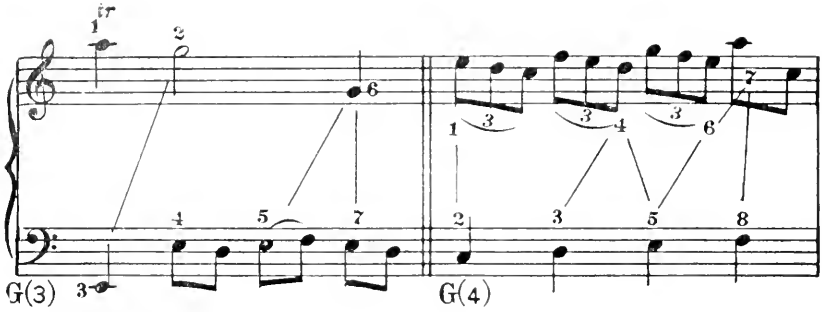
Under each type of music was given first the mean span of perception and then the range, as in Table 1. The material selected to obtain these figures consisted of 100 cards for melodic, 40 for polyphonic, and 100 for harmonic material for each subject. The same material was used for calculations in all trials for any one subject, but the same material was not used for all subjects. Each reader was tested at the level of difficulty at which he did best. Material that was far too easy or entirely

too difficult for a reader yielded inferior results; obviously, therefore, though it had been practiced, it was not included for purposes of measurement of progress.

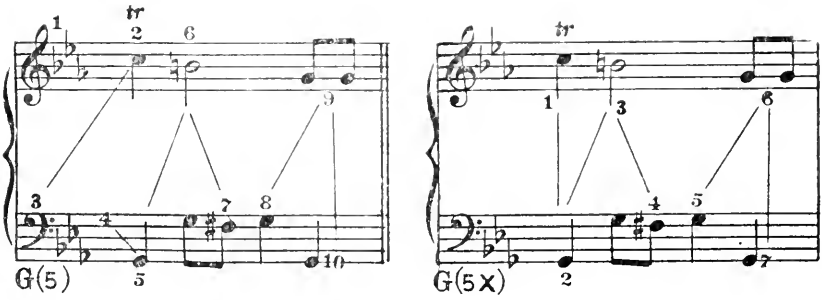
In the last column is given the manner in which the majority of the cards were read during each trial. Every subject read some cards by recognition of the form of the entire pattern, and other cards by picking out one or two notes as cues, filling in the rest subjectively, but the dominance of one or the other method was obvious in nearly every individual. Some changed their manner of recognition on a large portion of the material as practice proceeded. This change was clearly demonstrated by the nature of their errors, and was recognized and reported in several cases by the subjects themselves.

A question may arise as to how the evaluation of a subject's reading at the end of a long period of practice may be compared with any degree of accuracy with one made at the beginning. To aid on this difficult point, the experimenter wrote down as nearly as he could the location and type of errors made by the subject as he played, keeping this record for comparison later. With extremely poor readers, this record could not be exact, but when errors were few, it was reasonably accurate. In every case of material improvement, the subject was aware of his own increased efficiency in sight reading at the piano. In eight cases, in which the subjects were studying music during the experiment, the music teacher confirmed the experimenter's belief as to the amount of improvement of these individuals.

Though training in harmony, counterpoint, and composition tended in general to increase the accuracy of reading, it did not necessarily insure high achievement. In some cases theory work made the performer so exact as to every detail that he could not attain any speed at all. Doubtless the acquaintance with rules of harmony aided in the anticipation of resolutions just as knowledge of grammar is helpful in rapid comprehension in book reading. Therefore more intelligent guessing might have been done by those with the theoretical background in the conventional sort of music. There were many without such a background, however, who demonstrated considerable ability to anticipate some



Numbers indicate approximate location of fixations made by subject E as he read the music. Arrows indicate the direction of motion of the eyes. In G 3 E made an error on next to the last note for the left hand, reading it as D. Accuracy was good otherwise.



Similarity in the reading of G 5 by subject E (left) and subject W (right). The signature was given before the exposure of 2 sec. Notice the irregularity of procedure near the first of E's reading where he tried to orient himself as to clefs and signature. Both readings were correct. Numbers indicate successive pauses.

FIG. 3

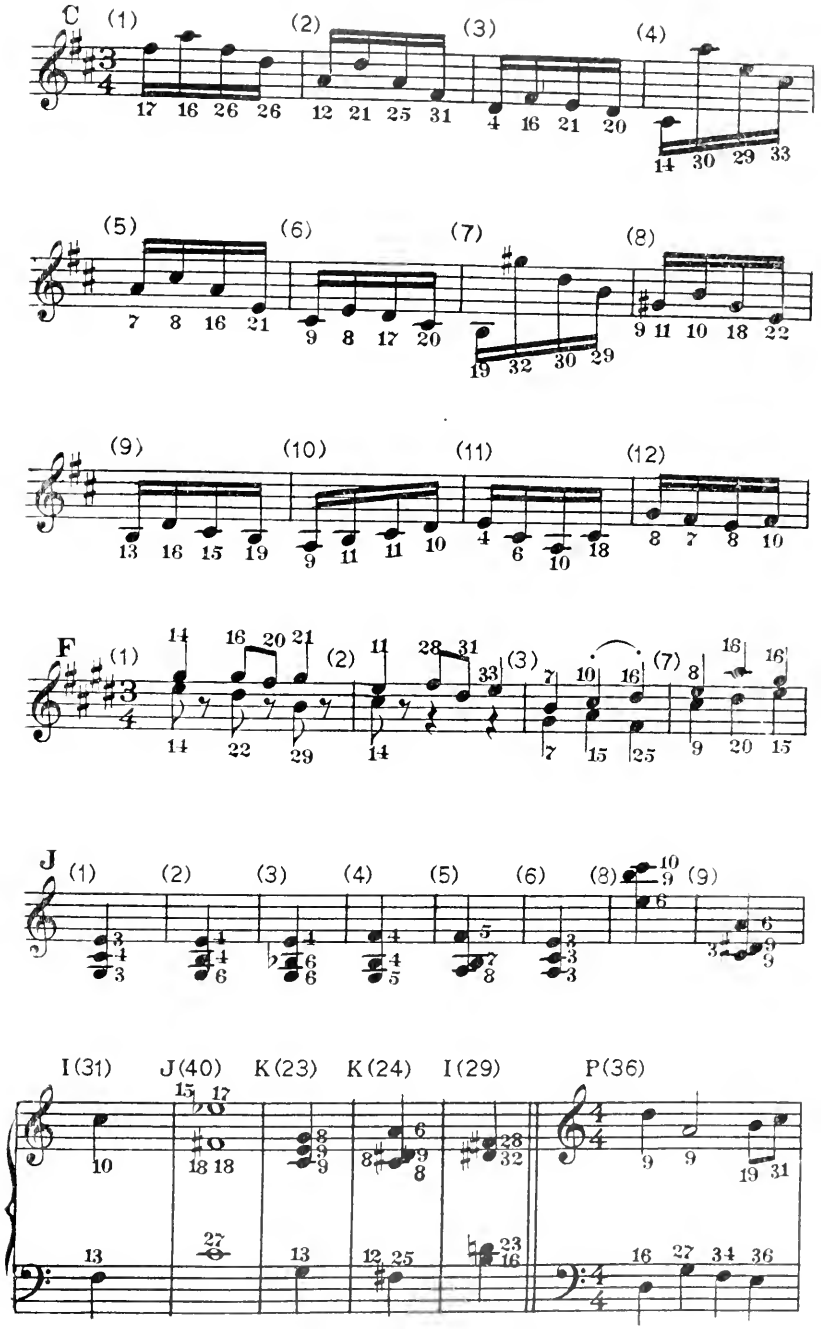


FIG. 4. LOCATION OF ERRORS.

Forty diagnostic subjects read these examples. Numbers by each of the notes indicate how many of them missed the note.

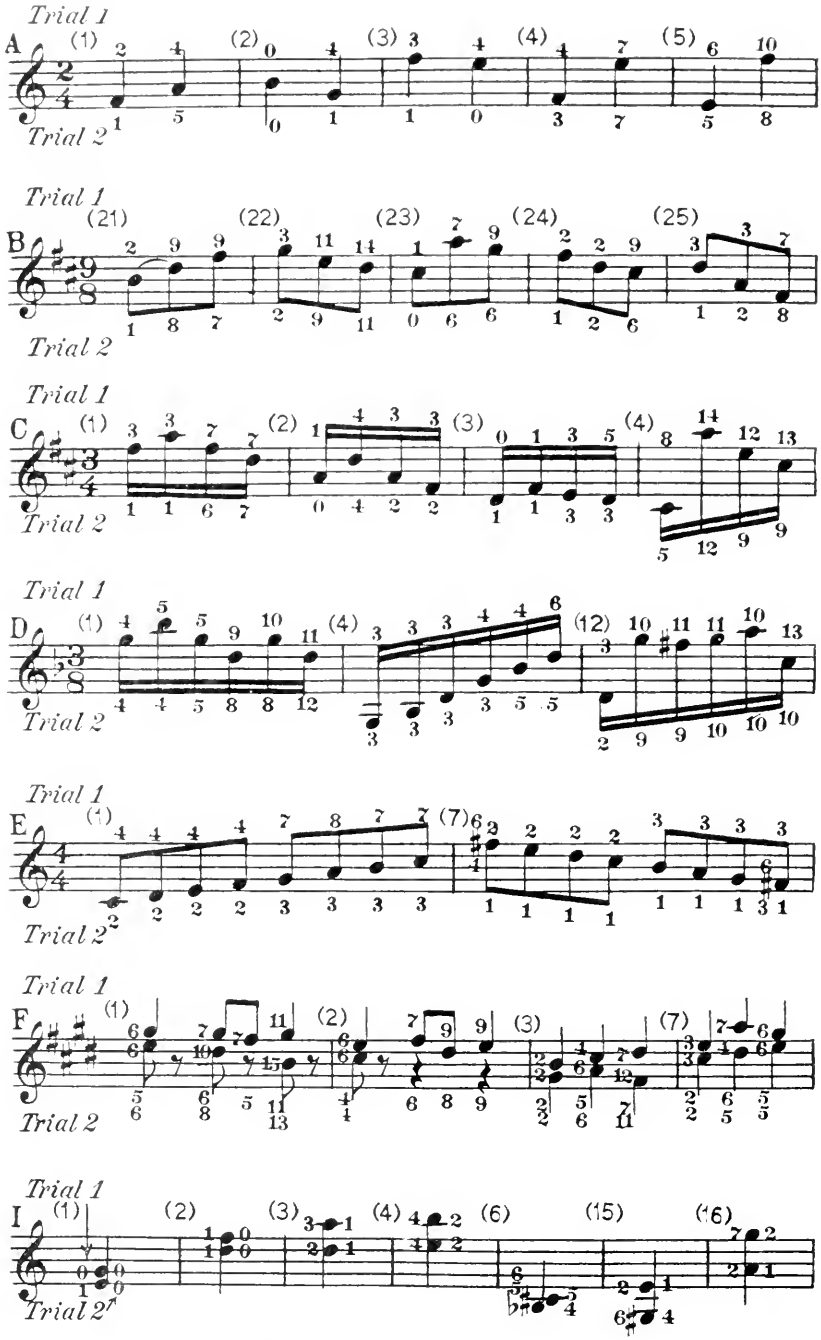


FIG. 5. ELIMINATION OF ERRORS.

Twenty-four practice subjects read these examples on two trials or more. Figures show how many of them made errors on each note for trials 1 and 2.

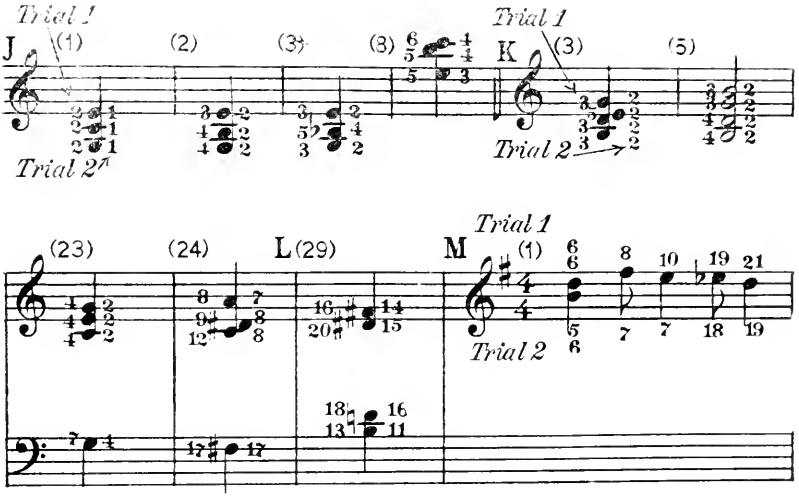


FIG. 5—CONTINUED

TABLE 2

Subject A—Training B.M. in violin, 1 yr. piano. Reading C—, playing C.

Trial	Time	Melodic		Polyphonic		Harmonic		Type of Reader
		M	R	M	R	M	R	
1.	92%	2.9	1–6	3.0	1–4	2.9	2–5	Part
2.	95%	3.1	1–6	3.0	1–4	3.1	2–5	Part
3.	96%	3.3	1–7	3.4	1–6	3.0	2–5	Pattern
4.	94%	3.5	1–6	3.3	1–6	3.3	2–5	Pattern
5.	97%	3.5	1–7	3.4	1–6	3.3	2–5	Pattern
6.	96%	3.5	1–6	3.2	1–6	3.4	2–6	Pattern

Final test of reading B—. Increased speed and accuracy.

Subject B—Training 10 yrs. piano (not with a good teacher, not recent). Reading E, playing D—.

Trial	Time	Melodic		Polyphonic		Harmonic		Type of Reader
1.	84%	2.1	1–4	2.4	1–5	2.4	1–4	Part
2.	88%	2.3	1–4			2.5	1–4	Part

Final test of reading D—. Insufficient speed, the same inaccuracy.

Subject C—Training B.M. in voice, 3 yrs. piano. Reading C—, playing C.

Trial	Time	Melodic		Polyphonic		Harmonic		Type of Reader
1.	89%	2.6	1–4	2.4	1–5	2.4	1–4	Part
2.	87%	2.8	1–6	2.4	1–5	2.3	1–4	Part
3.	87%	2.2	1–6	2.3	1–5	2.3	1–4	Part
4.	90%	2.5	1–6	2.4	1–5	2.5	1–4	Part

Final test of reading C. Very little if any improvement.

Subject D—Training B.M. in voice, 7 yrs. piano. Reading C, playing C.

Trial	Time	Melodic		Polyphonic		Harmonic		Type of Reader
1.	94%	2.7	1–6	3.0	1–6	3.4	1–6	Pattern
2.	96%	3.2	1–6	3.2	1–7	3.5	1–5	Pattern
3.	96%	3.8	1–8	3.6	1–7	3.8	1–6	Pattern
4.	96%	3.6	1–8	3.5	1–7	3.8	2–6	Pattern
5.	97%	4.1	1–8	3.9	1–7	3.7	2–6	Pattern

Final test of reading B—. Increase in accuracy chiefly.

Subject E—Training 9 yrs. piano. Reading C, playing B.

Trial	Time	Melodic		Polyphonic		Harmonic		Type of Reader
1.	95%	3.8	1–8	3.2	1–5	3.8	1–6	Pattern
2.	96%	4.1	1–8	4.0	1–7	3.9	1–7	Pattern
3.	96%	4.0	1–8	3.8	1–7	3.9	2–7	Pattern
4.	95%	4.0	1–8	4.1	1–7	3.9	1–7	Pattern

Final test of reading B—. Increase in speed and accuracy.

Subject F—Training 9 yrs. piano. Reading C—, playing B.

Trial	Time	Melodic		Polyphonic		Harmonic		Type of Reader
1.	91%	2.6	1–6	2.1	1–4	3.0	1–4	Part
2.	89%	2.9	1–8	2.4	1–6	3.1	1–4	Part
3.	92%	2.9	1–8	2.3	1–6	3.3	2–6	Pattern
4.	91%	3.2	1–8	2.6	1–6	3.5	2–6	Pattern
5.	92%	3.3	1–8	2.9	1–7	3.6	2–6	Pattern

Final test of reading B—. Greater speed. Accuracy slightly better, but still quite imperfect.

TABLE 2—CONTINUED

Subject G—Training 8 yrs. piano, considerable theory. Reading D, playing C+ (slow reaction time but accurate).

Trial	Time	Melodic		Polyphonic		Harmonic		Type of Reader
1.	92%	3.0	1–6	3.5	1–7	3.2	1–5	Pattern
2.	93%	3.4	1–8	3.6	1–7	3.7	1–6	Pattern
3.	95%	3.6	1–8	3.8	1–7	3.8	2–6	Pattern
4.	95%	3.6	1–8	3.7	1–7	3.8	2–6	Pattern
5.	97%	4.1	1–9	4.4	1–8	3.9	2–6	Pattern

Final test of reading B—. Increased speed and accuracy.

Subject H—Training 7 yrs. piano, considerable theory. Reading D, playing B (very slow and inaccurate).

Trial	Time	Melodic		Polyphonic		Harmonic		Type of Reader
1.	82%	2.4	1–6	2.3	1–4	2.5	1–4	Part
2.	86%	2.6	1–6	2.4	1–4	2.6	1–4	Part
3.	89%	2.8	1–8	2.4	1–4	2.8	1–5	Part
4.	87%	2.9	1–8	2.5	1–5	2.9	2–5	Part
5.	85%	3.0	1–8	2.7	1–6	3.1	2–5	Pattern

Final test of reading D+. Still very slow but more accurate.

Subject I—Training 7 yrs. piano, some violin, almost no theory. Reading C, playing B.

Trial	Time	Melodic		Polyphonic		Harmonic		Type of Reader
1.	94%	3.5	1–6	3.6	1–6	3.6	2–6	Pattern
2.	96%	3.6	1–6	3.8	1–6	3.6	2–6	Pattern
3.	96%	3.8	1–6	3.9	1–6	3.7	2–6	Pattern
4.	96%	4.0	1–8	4.0	1–7	3.9	2–7	Pattern
5.	97%	4.3	1–8	4.2	1–7	3.9	2–7	Pattern

Final test of reading B. Increase in speed and accuracy.

Subject J—Training 7 yrs. piano. Reading C—, playing C

Trial	Time	Melodic		Polyphonic		Harmonic		Type of Reader
1.	87%	2.7	1–6	2.8	1–5	2.8	1–4	Part
2.	94%	2.9	1–8	3.0	1–5	2.9	1–4	Part
3.	93%	3.2	1–8	3.0	1–5	3.1	2–5	Pattern
4.	94%	3.3	1–8	3.1	1–5	3.1	1–5	Pattern

Final test of reading C. Increased speed.

Subject K—Training 6 yrs. piano. Reading D, playing B.

Trial	Time	Melodic		Polyphonic		Harmonic		Type of Reader
1.	94%	1.9	1–4	2.0	1–4	2.0	1–4	Part
2.	94%	2.2	1–8	2.2	1–5	2.7	1–4	Part
3.	94%	2.3	1–8	2.4	1–5	2.8	1–4	Part
4.	93%	2.5	1–6	2.5	1–5	3.1	1–4	Pattern

Final test of reading C. Speed increased, but inaccurate.

Subject L—Training 6 yrs. piano. Playing B, reading B—.

Trial	Time	Melodic		Polyphonic		Harmonic		Type of Reader
1.	95%	3.2	1–8	3.3	1–7	3.7	1–5	Pattern
2.	92%	3.7	1–8	3.6	1–7	3.8	1–6	Pattern
3.	94%	4.0	1–8	4.0	1–7	3.9	1–6	Pattern
4.	95%	4.3	1–8	4.1	1–7	4.0	2–7	Pattern
5.	94%	4.4	1–8	4.2	1–7	4.0	2–7	Pattern

Final test of reading B+. Practically flawless except time.

TABLE 2—CONTINUED

Subject M—Training 6 yrs. piano. Reading D, playing C.

Trial	Time	Melodic		Polyphonic		Harmonic		Type of Reader
1.	92%	2.0	1–4	2.1	1–4	2.3	1–4	Part
2.	91%	2.2	1–6	2.2	1–5	2.6	1–4	Part

Final test of reading D+. Fast and careless.

Subject N—Training 6 yrs. piano. Reading D—, playing C.

Trial	Time	Melodic		Polyphonic		Harmonic		Type of Reader
1.	85%	2.7	1–4	2.5	1–5	2.6	1–4	Part
2.	88%	3.0	1–6	2.7	1–5	2.8	1–4	Part
3.	92%	3.1	1–6	3.0	1–6	2.9	2–5	Pattern
4.	94%	3.1	1–6	3.0	1–5	3.0	1–5	Pattern
5.	92%	3.3	1–8	3.1	1–5	3.3	2–5	Pattern

Final test of reading C. More accurate, but many hesitations. Subject has some technical difficulty in playing.

Subject O—Training 5 yrs. piano. Reading D, playing C.

Trial	Time	Melodic		Polyphonic		Harmonic		Type of Reader
1.	89%	1.9	1–4	1.8	1–4	2.4	1–4	Part
2.	86%	2.4	1–5	2.0	1–4	2.5	1–4	Part
3.	89%	2.5	1–6	2.1	1–4	2.5	1–4	Part
4.	87%	2.4	1–6	2.0	1–4	2.7	1–4	Part
5.	89%	2.6	1–6	2.1	1–4	2.6	1–4	Part

Final test of reading C—. Increased speed, low accuracy.

Subject P—Training 5 yrs. piano. Reading D—, playing C.

Trial	Time	Melodic		Polyphonic		Harmonic		Type of Reader
1.	90%	2.8	1–4	2.5	1–4	2.9	1–5	Part
2.	91%	3.0	1–6	2.8	1–5	2.9	1–5	Part
3.	94%	3.3	1–6	3.1	1–6	3.2	2–5	Pattern
4.	93%	3.2	1–6	3.1	1–6	3.3	1–5	Pattern
5.	96%	3.4	1–8	3.3	1–6	3.6	1–7	Pattern

Final test of reading C. Accurate, but many hesitations.

Subject Q—Training 4 yrs. (Age 13 yrs., 8th grade.) Reading F, playing C. Reads one note at a time only.

Trial	Time	Melodic		Polyphonic		Harmonic		Type of Reader
1.	65%	1.5	1–4	1.5	1–3	2.0	1–4	Part
2.	75%	2.0	1–4	1.7	1–4	2.1	1–4	Part
3.	90%	2.1	1–5	1.6	1–4	2.1	1–4	Part
4.	86%	2.2	1–5	1.8	1–4	2.4	1–4	Part

Final test of reading D—. Still very slow and stumbling.

Subject R—Training 3½ yrs. piano. Age 14 yrs., 10th grade. Reading C—, playing B—. Considered a child prodigy.

Trial	Time	Melodic		Polyphonic		Harmonic		Type of Reader
1.	90%	2.9	1–8	2.6	1–5	2.5	1–4	Part
2.	92%	3.1	1–8	2.9	1–6	3.0	1–6	Pattern
3.	94%	3.1	1–8	3.1	1–6	2.9	1–5	Pattern
4.	94%	3.2	1–8	3.1	1–6	3.0	1–5	Pattern
5.	96%	3.6	1–8	3.5	1–7	3.5	2–6	Pattern

Final test of reading B—. Increased speed and accuracy.

TABLE 2—CONTINUED

Subject S—Training 3 yrs. Reading C, playing C.

Trial	Time	Melodic		Polyphonic		Harmonic		Type of Reader
1.	93%	3.1	1–8	3.0	1–5	3.1	1–4	Pattern
2.	91%	3.5	1–8	3.3	1–6	3.5	1–5	Pattern
3.	93%	3.7	1–8	3.4	1–6	3.8	1–6	Pattern
4.	93%	3.4	1–8	3.4	1–6	3.8	1–6	Pattern
5.	95%	4.1	1–8	3.8	1–7	4.0	1–7	Pattern

Final test of reading B. Accuracy increased; speed slow.

Subject T—Training 3 yrs. piano. Reading C, playing B—.

Trial	Time	Melodic		Polyphonic		Harmonic		Type of Reader
1.	80%	2.4	1–6	2.3	1–5	2.5	1–4	Part
2.	87%	2.8	1–6	2.5	1–5	2.8	1–4	Part
3.	91%	2.9	1–6	2.9	1–5	3.1	1–4	Part

Final test of reading C+. Technique inadequate for speed.

Subject U—Training 2 yrs. piano, 2 yrs. voice. Reading D—, playing C.

Trial	Time	Melodic		Polyphonic		Harmonic		Type of Reader
1.	86%	2.1	1–4	2.0	1–4	2.1	1–4	Part
2.	88%	2.2	1–4	2.0	1–5	2.2	1–4	Part
3.	90%	2.2	1–6	2.3	1–5	2.2	1–4	Part
4.	93%	2.5	1–5	2.4	1–7	2.4	1–4	Part
5.	93%	2.8	1–6	2.6	1–6	2.7	1–5	Part

Final test of reading C—. Accuracy much greater, still slow.

Subject V—Training 2 yrs. piano. Reading D, playing C.

Trial	Time	Melodic		Polyphonic		Harmonic		Type of Reader
1.	89%	3.0	1–8	2.8	1–4	2.9	1–4	Part
2.	92%	3.2	1–8	3.1	1–5	2.9	1–4	Pattern
3.	90%	3.5	1–8	3.2	1–5	3.1	1–4	Pattern

Final test of reading C. Increased speed, still inaccurate.

Subject W—Training 2 yrs. piano. Reading C, playing C.

Trial	Time	Melodic		Polyphonic		Harmonic		Type of Reader
1.	94%	3.2	1–8	2.1	1–5	2.5	1–4	Part
2.	95%	3.5	1–8	2.1	1–4	2.6	1–4	Part
3.	95%	3.6	1–8	2.4	1–5	2.8	1–5	Pattern
4.	95%	3.7	1–8	2.4	1–5	2.7	1–4	Pattern

Final test of reading B—. Remarkable speed for two years training, but accuracy low.

Subject X—Training 1½ yrs. piano. Reading E, playing C—.

Trial	Time	Melodic		Polyphonic		Harmonic		Type of Reader
1.	70%	1.3	1–3			1.6	1–4	Part
2.	75%	1.5	1–4	1.1	1–3	1.7	1–4	Part
3.	79%	1.8	1–4	1.1	1–3	1.6	1–4	Part

Final test of reading D—. Reads one note at a time.

TABLE 2—CONTINUED

Comparison of Group Mean Scores by the Critical Ratio Technique, All 24 Subjects

Time	Mean	S.D. of Difference	D./S.D.	Chances in 100 of a Difference
Trial 1.	88			
Trial 2.	89.8	4.18	.43	66
Melodic				
Trial 1.	2.6			
Trial 2.	2.88	.17	1.64	95
Polyphonic				
Trial 1.	2.49	.192	.99	84
Trial 2.	2.68			
Harmonic				
Trial 1.	2.71			
Trial 2.	2.89	.154	1.17	87
Same for 13 Subjects Who Practiced Five Trials				
Time				
Trial 1.	90.23			
Trial 5.	93.87	1.42	2.5	99
Melodic				
Trial 1.	2.75			
Trial 5.	3.57	.192	4.3	100
Polyphonic				
Trial 1.	2.707			
Trial 5.	3.39	.24	2.8	100
Harmonic				
Trial 1.	2.92			
Trial 5.	3.48	.148	3.8	100

notes not really seen clearly. How much guessing was done cannot be exactly determined, because unfamiliar groupings of notes in which guessing was impossible were not seen as wholes at all. They were deciphered, not read.

Experience in playing with a jazz orchestra resulted, in three cases, in rapid, but careless reading. These three individuals reacted quickly, but they did more surmising than perceiving. They failed miserably on melodic patterns and polyphonic music, but they found chords a little easier. They are listed in the table as J, M, and T. Subject J cured his careless tendencies, which were less in degree than those of the other two, who were careless throughout. Subjects J and T plunged ahead fast with little inhibition, and J especially took in large patterns at a glance, but both made numerous errors in details, especially in the melodic groups.

A few selected examples will illustrate how improvement was

recognized. Subject A, during her first trial, was able to grasp only one or two notes of a melodic pattern, usually at the beginning of the group. She showed by the errors that she made that she had no idea, as a rule, what the shape of the rest of the pattern was. She guessed at one or two notes beyond those she saw clearly, according to her report, and was right slightly more often than she was wrong. She reported a few times that she saw an entire group of six notes as a whole, but in every case the notes followed a scale or easy broken chord pattern up or down with no irregularities. She read polyphonic examples in the same manner. Chords for one hand appeared to her as wholes if very simple. Two-hand chords were rarely possible for her, and she reported that she guessed at one hand or the other, and did not see the entire chord clearly. Ultra-modern material did not register. One or two notes were all that she could read correctly, and no guessing was possible. The material in the comparison series gave further evidence for all of the above statements.

On trial 2 the errors were surprisingly similar to those on trial 1. Approximately 75 per cent of the cards that were wrong the first time were also wrong the second time they were read, and the mistakes were in the majority of these cases identical. There were a few cards incorrect on the second trial that were correct on the first, and a somewhat greater number of cases in which the reverse was true. A reported that she could see whole groups more frequently on the second trial than she did before, but that these patterns were so vague to her that she was never sure whether she got any of the notes right or not. In six such instances she played the entire pattern too high by one line, and in two cases too low by the same amount, but she grasped the relative position of the notes perfectly. She made only two responses similar to the above on the first trial.

On trial 3 for all types of material, A became a pattern reader predominantly, though she still resorted to analysis far too often. She reported that the patterns had ceased to be so vague to her, and she seldom misplaced them on the staff. She increased in both speed and accuracy on trial 4, but trials 5 and 6 showed no material gain except in time. Her final test without the appa-

ratus demonstrated performance which would not have been possible by her former method of reading. She was conscious that she was perceiving patterns as she went along, and that she was anticipating what she was about to play before playing it. The absence of any anticipation had caused stumbling in her reading previous to the practice. After the experiment, little trace of the stumbling was left.

Subject B, having neglected music for a number of years, gave unsatisfactory results, but managed to improve slightly.

Subject G was predominantly a pattern reader from the start, but she read slowly with fairly high accuracy. Her improvement consisted in learning to react more quickly, take in larger patterns at a glance, and read accidentals as a part of each pattern. She had the peculiar habit mentioned before of reading notes first and adding sharps, flats, or naturals afterwards, taking her time to the latter. Throughout the first three trials, a marked delay in reaction occurred every time a sharp, flat, or natural occurred. More than one accidental persistently resulted in loss of the impression of what was read before a response could be made. When no accidentals were present, the reaction time was short by the second trial, and the response was accurate, even if the pattern included seven or eight notes if these were not too irregular in arrangement. The subject could read two-hand chords far better than the average provided not more than one accidental were present. On trial 5 for all types of material, G showed marked improvement in her peculiar disability, and reported that she had become able to grasp sharps, flats, and naturals along with the notes more often than before. The final test of her reading showed that she was still too slow, but had gained some in speed, and considerably overcame her hesitant manner of reading before the experiment, which may have been caused partly by nervousness.

Subject H, who has been mentioned before, was considered gifted, had a phenomenal memory, and played with facility a broad repertoire. Several outstanding teachers have attempted to correct his pronounced reading disability. With his own persistent coöperation, all efforts failed completely. His improve-

ment was gradual. At first he used one or two notes as cues, and typically spent over two seconds figuring out his response before he could begin to play. Any rhythmic patterns were likely to give him trouble, and he hesitated frequently, seldom keeping a steady tempo. Until the last trial, he could not read chords for both hands with any certainty at a glance. He persistently failed with unusual chords throughout the practice, though he has memorized a considerable amount of contemporary music from several composers. Near the end H averaged slightly more than one second in his reaction time, and he reported that he saw the groups of notes as wholes on a little over half of the cards. The location and nature of his errors confirmed this report. However, his inhibitions and slow, careful habits seemed to persist to some extent in his sight-reading after the experiment.

Interesting as compared with H is subject I, whose reading was superior to that of H in every respect even though her training was inferior. She had studied very little theory, put no extraordinary effort into improving her sight-reading, memorized comparatively little, and played almost no music in ultra-modern idioms. She depended upon the printed page nearly always when she played. This last fact may account partly for her efficiency in reading, but it does not explain how she can grasp some unusual and irregular groupings which are probably foreign to her experience, while H, who must have played many such patterns, persistently failed to read them. The improvement of I consisted in increasing the span of perception, and her progress was steady.

The best reader in the entire practice group was the gifted 17-year-old pianist L. She grasped patterns of three or four notes with ease from the start, and later took in a six-note span with a surprising accuracy approaching that of the best professional musicians in the diagnostic group. She shortened her reaction time during practice, and became a rapid as well as accurate reader. She made approximately three-fourths of her errors persistently on three or more of the five trials. Improvement seemed next to impossible on all material that was spread out over a wide area. Series M and the first part of Series B

gave her the most trouble for this reason. The last 20 cards of Series A failed to improve much for the same reason. L read two-hand chords with ease unless they covered a vertical distance of 1¾ inches or more. She read nearly all of Series L, consisting of unusual chords, with less difficulty than any other subject on all trials, and nearly equaled two experienced professionals on her last trial. She, like subject I, could give no clue introspectively as to how she perceived these unusual groupings, which she often could not name as altered dominant sevenths, ninths, or whatever they were. She claimed that they had meaning for her, however, even if she could not identify them easily as to harmonic structure.

Some of the subjects, as may be seen from Table 2, made steady advancement, while others were inclined to reach a plateau or to backslide occasionally during practice. Interest was uniformly good throughout, except as it was affected by moods or health in rare instances. The writer would infer that on the last trial the subjects were apparently stimulated to greater effort in a few cases by the feeling that they must make the best of their last chance to improve. A few records indicate such a motivation, which ended a plateau with a sudden jump to much higher efficiency. After the practice several subjects were amazed at their own increase in speed and accuracy of sight-reading. One stated that he could now read so fast that his fingers could not keep up with his eyes. Others expressed their reaction to their gains in efficiency with words to the same effect.

V. Conclusions

Within limits determined by the kinds of music that were used, the results of this investigation prove conclusively that in the group of 74 subjects tested, which we may assume to be typical of professional, student, and amateur musicians, the ability to grasp a musical pattern of three or more notes at a glance when necessary is absolutely essential to rapid and accurate reading. No exceptions to this rule were found, and Jacobsen's results tend to support this conclusion.

Readers who typically see one or two notes which serve as sensory cues fill in the remainder subjectively. They read only part of the pattern and guess the rest of it. They may therefore be classified as part readers, and they are, without exception, less efficient than pattern readers, who use the form of the whole as a cue to recognition for most of the material that they read. Other things being equal, the larger the patterns grasped, the faster is the maximum speed of accurate reading.

There seems to be a very low positive correlation between years of musical training and span of perception in the tables for all types of material, but a slightly higher correlation in the case of polyphonic music than for the other two classes. Since years of study make a poor index to achievement, and no more accurate measure of accomplishment was applied to all subjects in this research, the writer feels that the exact coefficients of correlation would mean little with the data for their calculation. Therefore we may omit detailed consideration of this matter, and proceed from these generalizations to more important specific conclusions.

1. *Musical Patterns that Are the Equivalent of Words.*—The influence of background is evident in the successes and failures of individual subjects on different cards. Each subject had a musical vocabulary, if that term may be used in such a connection, which may be said to correspond to his English vocabulary in that configurations frequently encountered in past experience evoked immediate recognition just as a familiar word would have done. A relatively unfamiliar word, on the other hand, must usually be subjected to analysis before its meaning is recognized, and an unusual musical figure must be treated in the same manner. We refer, for proof of this, to the preceding chapter in which was mentioned the fact that several subjects reported that for some cards the meaning was not immediate. It was nonsense to them until they subjected it to analysis, and learned how it sounded.

Several degrees of difficulty of perception should be distinguished in order to show what constitutes complexity in printed music. A few general considerations will be given first, then more specific conclusions in regard to this matter. The duration

of the notes plays the major rôle in determining what will be the perceptual unit. In case of half notes played at a very slow tempo, one note constitutes such a unit, according to the results with Series B, cards 1 to 20. The time signature determines the groupings to some extent. The distribution of notes on the staff is important. In Series A, for example, card 21 (see Fig. 2), the average reader failed to see the F clearly. He saw only the first two notes as a unit, and anticipated the third note out in the periphery as belonging to a separate unit to be shifted to later. With eighth notes crowded more closely as in Series B, card 21, the typical reader saw all three notes as a unit. Therefore number of notes alone does not determine difficulty. In Series E, card 1, for example, any observer who had played scales from the page to any extent recognized the scale on the card, and got the eight notes right if he did not misplace the entire scale. All that he was required to do in order to respond correctly was to use the form as a cue and be careful to observe where on the staff the scale started. In the case of D 12, for example, the pattern consisted of only six notes, but the arrangement was irregular and unusual, and the best pattern readers sometimes missed it.

By analysis of the errors on numerous examples with all subjects for several kinds of material, the experimenter was able to arrive at a number of interesting, more specific conclusions.

For melodic material, the following was the order from easiest to most difficult patterns in general for a typical reader: ascending stepwise progressions, descending stepwise progressions, ascending broken chord progressions following a simple major or minor triad, descending examples of the same, ascending chromatic progressions, descending chromatic progressions, alternations between two notes a third or more apart, broken seventh chords, broken altered chords, irregularly ascending groups skipping sometimes one step and sometimes two, descending examples of the same, and irregular groupings with some wide skips and one accidental.

The operation of two factors was clearly seen to control the difficulty of the material. One was the frequency with which

the pattern occurred in the musical experience of the observer. Another was the number of elements, including sharps, flats, and naturals, that composed the pattern. Chromatic passages or altered chords contained accidentals, which increased the difficulty. Otherwise frequency explains the order of difficulty except for the curious fact that ascending passages were read with greater success than descending passages, while both occurred about an equal number of times during the experiment. The difference was small, but reliable in each case. The writer believes that the slightly greater difficulty of playing descending passages on the piano experienced by performers not too highly skilled may have resulted in worse reading habits coming down than going up, but this is only a tentative explanation.

The six-note groups were more easily grasped than those of five or seven notes. Five were usually played as six, and seven as eight, or six. Here again the rarity of fives and sevens in music played by the observers operated as a confusing factor. Also the four-, six-, and eight-note gestalten are frequently capable of being subdivided into smaller groups. Six notes may appear as two groups of three or three groups of two, and eight as two groups of four or four groups of two, etc. This subdivision facilitates reading.

Rhythms involving quarter notes and eighths interspersed were more easily read than the same sort of patterns with eighths and sixteenths. In the latter case the distinction was difficult because the number of flags on each stem had to be observed. If bars connected the notes instead of flags being placed on each individual stem, the perception of rhythms was easier, because the bars unified the whole by binding the notes together. This Gestalt principle is often encountered in other categories of objects. Most printed music is patterned conveniently for reading of rhythmic groups, but exceptions can be found.

Other things being equal, most subjects had greater difficulty with the bass than with the treble staff, probably because the latter was relatively less familiar to them.

As might be expected, the greater the number of sharps or flats in the signature, the more confusing was the material, and

without exception sharps gave the subjects more difficulty than flats. The more sharps or flats the observer must keep in mind, the more complex is his task, even though he is not required to perceive more elements. Therefore a mental set for four sharps, for example, adds new elements in the mind of the observer which would not be there in the key of C major at all. Why flats should ordinarily be less difficult than sharps is not clear to the writer.

Parallel motion of two melodic lines was more easily perceived than contrary motion. Probably the relatively greater frequency of parallel motion in most music accounts for the fact that notes fit together into a whole better in this kind of structure. However, parallel motion at the interval of a fourth or a seventh caused great confusion. The former were most frequently misread as thirds, and the latter as octaves. The readers tended to conform to the pattern which they had frequently played which closely resembled what they saw. Parallel fourths or sevenths seemed illogical to them.

Though intricate rhythms could often be read in one melodic line, any simple lack of coincidence of the time values in two-part polyphonic selections gave trouble. There were certain notes in one part or the other which seemed to stand outside of the pattern. They seemed to be excluded, as it were, from the unit being read. Therefore perception at a glance of the time relations of two simultaneous melodic lines were almost impossible except for the very best readers. The conclusion that certain notes were excluded from the Gestalt at times is further substantiated by the fact that these notes were nearly always misplaced, while the other notes in the same group were correct.

More than two parts in counterpoint did not seem to be read in patterns consisting of one or more notes from each of the melodic lines unless three or four notes fell in a vertical arrangement as in a chord. If this vertical arrangement did occur, the chord was read as a whole, but if the fitting together of the different tone values was at all intricate, the best readers failed to take in all parts at a glance. Probably frequent shifts from one part to another were always necessary, as Jacobsen's results indi-

cated, but how rapid and accurate reading is thus possible with such material remains a mystery to some extent. The reason for the failure to grasp all parts at a glance is clear since the notes are separate, distinct units, unconnected usually by stems or any other lines that would tend to unify them into patterns.

The fact that notes on lines appeared to be different entirely from those in spaces would indicate that the staff was part of the figure and not ground in the usual Gestalt sense of the term.

With two-note chord material for one hand, the intervals in order from easiest to most difficult to read were as follows: thirds, fifths, octaves, seconds, fourths, sixths, and sevenths. This conclusion is only tentative, however, since not enough examples of each interval were used to eliminate other factors, such as position on the staff, etc. Very little experimental evidence can be given to support any explanation of this order of difficulty, which may have been partly a matter of mere chance. However, the writer believes that when both notes were on lines or both in spaces as in the case of thirds and fifths, the mere likeness of the elements facilitated recognition. Octaves came next probably because of their frequency in music. Sixths were wide apart, had unlike elements—one note on a line and the other in a space—and were less frequent than octaves. Sevenths had like elements, but spread far apart. They were often mistaken for octaves, which are more frequent in occurrence.

Triads were most easily read in their fundamental positions, in which all three notes are on lines or all in spaces, and even distances apart. Neither of these conditions holds in other positions, in which one note is always removed a fourth from the other two. More complex chords followed the same laws. Some elements on lines and others in spaces added to the difficulty of perception. Distribution at equal intervals apart formed a better Gestalt than uneven distribution. As said before, seventh, ninth, and altered chords were more difficult than triads because there were more elements to be seen, and besides this the average reader in the group was not much experienced with seventh, ninth, or altered chords. There was some difference also in the unity of the pattern depending upon whether the elements were

connected by one stem or separated into two parts for two hands. The more unusual chords gave more trouble for this reason than did the triads.

Reading at a glance, subjects were able to grasp a few chords written on one staff for the right hand easily, while they experienced difficulty with the same combinations written in such a way that two notes were on one treble staff, and one, or possibly two, on another treble staff. The larger field that must be covered when reading for two hands at once may account for this. However, another factor seems to have entered into this situation, and that was the strong tendency that nearly all subjects had to think of the left-hand part as being on the bass staff. The uncommon use of treble staff for both hands was rare in their experience, and when it had occurred, slow deciphering was the result. A few examples proved that the same left-hand part could be read with greater ease in the bass than it could in the treble, even though the notes were identical.

The vast majority of the observers could respond most easily by playing on the keyboard. Therefore any difficulty with the motor act in the response was due to insufficient training, and only two cases of such a difficulty were discovered. Both were slight. If any difficulty was experienced by other observers in the transfer of the visual perception into a response, the trouble was obscure so far as the observers were concerned. The performance of observers on comparison cards, in so far as an accurate measure of it was possible, matched so closely the results at the piano that the difficulty in transfer to the keyboard seemed of minor importance as a rule. However, other phases of the reading process involving imagery and anticipation of action are yet to be worked out.

The problem of the relative importance of optical complexity and musical complexity offers a number of rather profound aspects. First in importance among these aspects is the question of which of these two ways of thinking of the musical pattern was dominant in the mind of the observer when he perceived the pattern. A question of this nature is usually difficult, if not impossible for the observer to answer subjectively. Some indi-

viduals claim that the visual pattern is what they look for in music, and that just how the visual meaning is transferred over into action is a mystery to them. Others state that they probably hear, at least vaguely, how the music sounds before they play it. This step in the transfer to the keyboard is impossible for some individuals, according to their reports, and each visual stimulus of a note means to them that they must press the appropriate key and that is all. They frequently express surprise at the unexpected sound that results.

Therefore the manner of transfer of visual perceptions to the keyboard remains a separate problem. This research goes far enough to suggest that wide individual differences in imagery determine whether optical or musical complexity of a Gestalt has the more confusing effect upon a subject. In the comparison series of this research were given two examples of stimuli in pairs in which the first of the pair was like the second in notes, but different only in visual appearance. In one case the only difference was that part of the stems were turned upward in one pattern and downward in the other. In the other case an arpeggio was printed with the notes distributed evenly for one stimulus, and with the same notes with one irregularity in their distribution on the other side. Those observers who appeared to be dominantly visual minded discovered the exact nature of the difference in each case, while those who were most concerned with the sound of the music invariably thought that different notes were in the two stimuli in both examples. They were unable to state what notes were changed, however, except in two or three cases in which the observers were sure that certain notes had been changed, and named the notes.

Another example is of value in illustrating the confusing effect of successive, optically dissimilar, but musically identical patterns. In Series I there was a two-note chord written A flat E flat which was followed by the chord G sharp E flat. Obviously both sound alike on the piano, and are played by pressing the same keys, yet confusion and delay occurred when the latter was seen because the combination of a sharp and a flat in one chord is rare in the sort of music most of them had played.

The inability to discriminate at a glance between an ascending scale passage and an ascending arpeggio may be regarded as a serious symptom of inaccuracy in reading. Such faulty observation was common among the less efficient readers until practice eliminated it in most cases. Similar inaccuracies were found in the reading of small irregularities in an otherwise uniformly ascending or descending progression. These also improved with practice.

The conclusion which may be tentatively proposed after careful analysis of these and other examples is that the readers who were habitually inclined to read one or two notes at a time, when forced to grasp larger units of material, saw only vague forms at first. They derived from their rather uncertain impression an idea of the direction of motion, but not the distance over the staff that the progression went, or even the intervals between the notes. Hence they often played too many notes or too few, totally disregarding the time. This often resulted in no improvement so far as figures in the table were concerned, but it should be regarded as the first step forward in learning to read by groups instead of single notes. There were several subjects who had advanced beyond this stage before starting the practice in this experiment, and these individuals saw the intervals between the notes more clearly and as a rule played the correct number of notes. The increase in clearness of the vague impressions of patterns, which many received at first, was gradual. If the practice had been continued for a longer period, a greater accuracy could have been obtained, the experimenter believes, than was possible at the end of the limited time. The first improvement that was evident was the larger units that the observer grasped, usually near the beginning of the second trial. After that the accuracy increased slowly. During the later trials the complexity of patterns that could be seen as wholes increased only a little, but more details were accurately observed than on earlier trials.

The fact that entirely new habits were set up as a result of practice with the tachistoscope is evident from the results of most

subjects. Why a few failed has already been explained, but why some started with correct methods of reading before the practice is unknown, since others under the same instructors in music had set up wrong habits. The methods of the former individuals were an accident. They were unconsciously picked up in spite of the over-analytical teachers.

The final test of reading with some new cards and some old cards revealed that the practice effects were general. As stated earlier, the subjects were as a rule unable to distinguish between old material that they had practiced and new material that they had not seen. The span of perception was about the same for both, though not enough new material of each type was used to furnish accurate figures for the table comparable with those for each of the practice trials. However, the final test showed that the new habits were generally applied effectively to any music to be read.

The close analogy between the reading of music and the reading of language has been clearly brought out in connection with the facts found. The good music reader must grasp units of four, six, or even eight notes just as he reads so many letters grouped together as a word. Therefore appropriately grouped notes form units that are in visual or auditory perception, or in meaning as related to their context, the equivalent of words in prose or poetry. They should then be read as such.

2. *Practical Application of This Research.*—The data obtained from the diagnostic and practice experiments suggests that a measure could be made of more individuals at each level of advancement in order to standardize a test of music-reading efficiency that could be applied by teachers. The same or similar material could be used with a much simpler means of exposure. The writer is attempting to construct a simple tachistoscope that may be mounted on the piano easily and used by teachers. He would propose that each teacher of piano make a record of the average span of perception of every pupil for different kinds of material. The types of errors made frequently by each should also be recorded. Then the resulting figures should be compared

with figures recorded in Table 1 and Table 2 of this investigation. The writer hopes that later some reliable norms will be available for comparison of the individual with a large number of others at his level of advancement in musical education.

If disabilities show up in the scores of any pupil, considerable time should be devoted to practice in reading cards in the tachistoscope until the pupil is forced to abandon unsuccessful methods of reading in favor of pattern reading. After considerable improvement is in evidence, a second test should be made to determine quantitatively the increase in complexity of patterns that can be used correctly. This will show the pupil his own improvement in clearly understandable form. The practice should not cease after this test. Much easy material should then be read at sight daily with the Gestalt principle in mind. If any sign of return to the old habits is observed, the teacher should practice the pupil with the tachistoscope again until backsliding has been checked. After several weeks' application of the new approach to continuous reading, another test should be made to make a quantitative measure of the improvement during that time.

Probably the tachistoscope measurement and practice is of little if any value until the pupil has automatized to a fair degree his response to single notes, even if he has not yet learned thoroughly signatures or accidentals. The teacher should see the destructive effect of continually calling the pupil's attention to the single note by scolding him whenever he happens to miss one. Corrections are necessary at times, but frequently the pupil should be urged to drive ahead rapidly with as few inhibitions as possible, even if he does make a few errors in the notes. In the end he will gain by acquiring skill in reading fast and accurately, while if he is constantly inhibited by fear of playing wrong notes, he will play the correct notes slowly and stumblingly.

The same procedure can be followed, but with different material, for the teaching of sight-singing. Educators are working in the right direction in this field already, but they have not gone far enough yet to have any accurate measure of the results that they are getting by pointing out tone groups to the children, or showing them flash cards. The groups that they are dealing

with are mostly phrases or logical divisions of the music, not perceptual units. The two are seldom identical. Further experiments with flash cards in the school room with controlled exposure time, may demonstrate that pattern reading can be taught along with sight-singing. However, reading the singing material on flash cards will probably prove insufficient for those who study piano or organ. Instrumental music requires quick grasp of rapid passages that could never be sung, and also of polyphonic selections and chords. The performer must learn to respond quickly upon his instrument, and to anticipate beforehand what he is to do.

Ordinarily musical material for the beginner is fairly well selected or composed so far as stages of difficulty in reading or playing are concerned. Little criticism of public school music material is to be made on this point. The groupings are printed in a manner that has been found by experience easiest to read, ordinarily. Only the method of teaching these materials should be changed in order to fall more in line with the Gestalt approach. The content rather than the arrangement of some of the music should be criticized, since frequently it is decidedly uninspired and uninspiring in nature.

The writer hopes that music reading may be made as enjoyable to everyone who can sing or play as novel reading is for most educated people. In order for it to be a joy instead of a pain, as it now is to many, this process must be made simpler, so that excessive strain is avoided, and pleasing results come as a reward for one's efforts. Training in the Gestalt approach to printed music should make this skill possible for many singers and players who would otherwise avoid reading whenever possible. No claim is to be made for such training as a remedy for all reading disabilities, but a cure for some inefficient habits has been proved possible in this research.

VI. Résumé

This investigation is a study of the complexity of musical patterns that can be perceived with one fixation of the eyes by

individuals with various degrees of musical training and experience, and of the effects of tachistoscope practice on the span of perception of these individuals for various kinds of musical material.

The tachistoscope mounted on a piano proved itself of value in measuring music reading efficiency for different kinds of material. The diagnostic experiment, with 50 subjects having various amounts of musical training from that of the professional to that of the beginner, proved conclusively that without exception efficient readers are able to grasp groups of three, four, or more notes at a glance. Slow, stumbling readers, on the other hand, are seldom able to grasp more than one or two notes at a time. On the basis of this distinction in fundamental reading habits, we may classify those who use the form of the entire group of notes as a cue to recognition as pattern readers, and those who see only one or two notes of a group and fill in the remainder subjectively as part readers. There is a low positive correlation between years of musical training and span of perception, or the amount of material that may be grasped as a unit at a short exposure. However, accomplished professional readers are able to read large patterns accurately at a glance even in the most intricate compositions.

Many excellent pianists and violinists are part readers, and their individual deficiencies proved quite interesting. Not all of them had the same disabilities, but in general they tended to spell out music or decipher it instead of really reading it. The inefficient habits that they had seemed to be rooted in their early training, and they had little or no insight concerning their difficulties. Several individuals were found who were not advanced in musical education, but were remarkably rapid and accurate readers, considering their background. They read mostly by patterns. They were totally unaware of the methods that they used as well as of the origin of their efficient habits.

Practice with the tachistoscope demonstrated that part readers may become pattern readers if their response to notes is sufficiently automatized. Approximately 20 to 30 hours of tachisto-

scope reading were required to make a substantial improvement in most subjects. Span of perception increased first and accuracy later in nearly all cases. The pronounced progress was evident to the subject in nearly every case, and in some instances the individual, who was formerly a stumbling reader, became able to read so fast that his fingers could not keep up with him. The experimenter's judgment as to the amount of improvement was in several cases confirmed by teachers who had the subjects under their instruction in piano.

With complete data available on every subject's errors with each card, the experimenter was able to classify his material as to the difficulty of various kinds of patterns. The results of a careful study of the kinds of errors that were persistent led to a Gestalt interpretation of music reading, which should be applied to learning in this field just as Gestalt already has proved valuable in teaching children to read language by large units. From the data we may conclude that a close analogy exists between the reading of words and the reading of music, for there are groups of notes which are definite perceptual units, and in this way the equivalent of words. Every musician has a musical vocabulary just as he has a vocabulary in English, French, or any other language. Any unfamiliar idioms must be deciphered until they are learned, but well known patterns should be recognized at a glance. Sometimes, however, wrong habits make immediate perception impossible.

This study has only attempted to classify music reading disabilities on the basis of errors made with varied patterns. There are numerous problems in this field which must be solved before the entire process of music reading is understood, but this investigation has stressed the importance of a neglected step in learning this skill of which most music teachers are ignorant, namely, the Gestalt approach to the process.

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